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ED 013 313 VT 001 875

ELECTRICAL TECHNOLOGY, A SUGGESTED 2-YEAR POST HIGH SCHOOL CURRICULUM.

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OFFICE OF EDUCATION, WASHINGTON, D.C.

REPORT NUMBER OE-80006 PUB DATE 60

EDRS PRICE MF-$0.50 HC-$5.08 127P.

DESCRIPTORS- ELECTRICITY, *TRADE AND INDUSTRIAL EDUCATION, *TECHNICAL EDUCATION, *CURRICULUM GUIDES, *CURRICULUM, *ELECTRONIC TECHNICIANS, EDUCATIONAL FACILITIES, INSTRUCTIONAL MATERIALS,

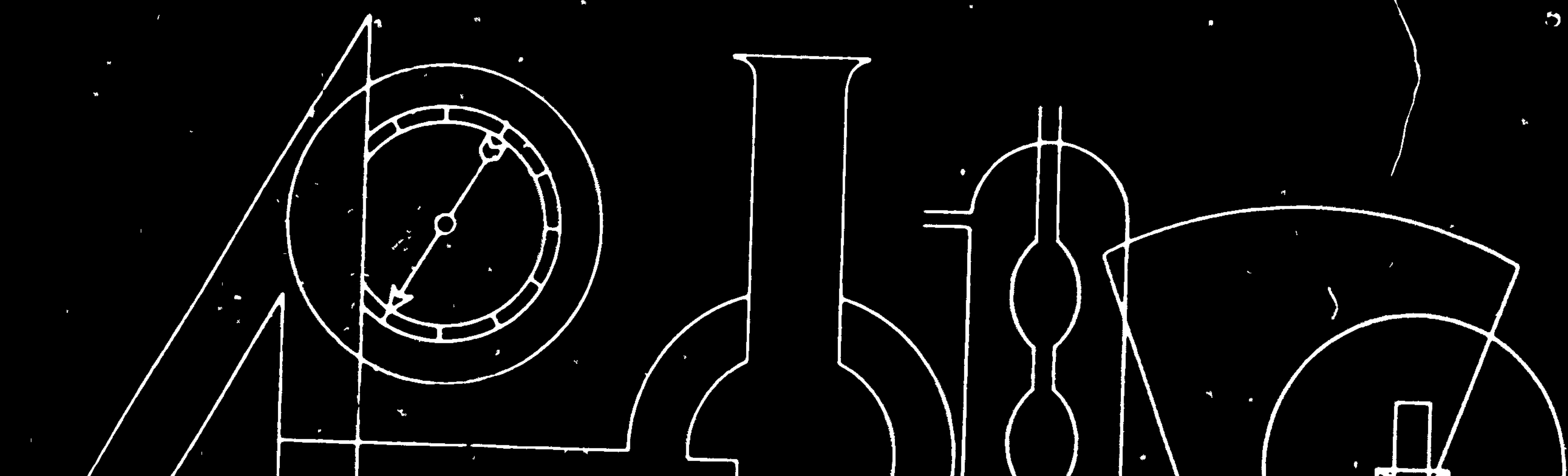
THE PURPOSE OF THIS CURRICULUM GUIDE IS TO AID ADMINISTRATORS, SUPERVISORS, AND TEACHERS PLAN, DEVELOP, AND EVALUATE PROGRAMS. TECHNICAL MATERIALS WERE PREPARED BY THE STAFF OF THE TECHNICAL INSTITUTE DIVISION OF THE OKLAHOMA STATE UNIVERSITY PURSUANT TO A U.S. OFFICE OF EDUCATION (USOE) CONTRACT. OTHER PORTIONS WERE PREPARED BY THE STAFF OF THE AREA VOCATIONAL EDUCATION BRANCH, USOE. TECHNICAL ACCURACY WAS CHECKED BY FIVE ELECTRICAL ENGINEERS. THE CURRICULUM IS PRESENTED AND DISCUSSED, AND COURSE OUTLINES GIVE -- (1) HOURS REQUIRED, (2) DESCRIPTIONS (COURSE), (3) MAJOR DIVISIONS (OUTLINE), AND (4) TEXTS AND REFERENCES. THE APPENDIX INCLUDES -- (1) EXAMPLES OF INSTRUCTIONAL MATERIALS, UNITS, LABORATORY EXPERIMENTS, REPORT WRITING STANDARDS, AND REPORTS, (2) FLOORPLANS, AND (3) LISTS OF EQUIPMENT AND SUPPLIES WITH COSTS. INSTRUCTORS MUST HAVE TECHNICAL COMPETENCE, INDUSTRIAL EXPERIENCE, AND PROFESSIONAL ACUMEN. STUDENTS SHOULD HAVE A GOOD GENERAL EDUCATION BACKGROUND WITH ONE OR TWO YEARS OF MATHEMATICS AND SCIENCE. THIS DOCUMENT IS AVAILABLE AS GPO NUMBER FS 5.280--80006 FOR 75 CENTS FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (EM)

OE-80006

AREA VOCATIONAL EDUCATION PROGRAM SERIES NO. 1

Electrical Technology

A Suggested 2-Year Post High School Curriculum



U S DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Office of Education

AREA VOCATIONAL EDUCATION PROGRAM SERIES NO. 1

ELECTRICAL TECHNOLOGY

A Suggested 2-Year Post High School Curriculum

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE . . . . . ARTHUR S. FLEMMING, *Secretary*
Office of Education . . . . LAWRENCE G. DERTHICK, *Commissioner*

Foreword

PHENOMENAL technological advances have been accomplished by scientists, engineers, mathematicians, and other technical workers including skilled craftsmen, with their specialized skills, working together as teams in developing new applications for scientific principles. The ever-increasing need for the combined talents of such teams has resulted in an unprecedented demand not only for the creative scientist and engineer, but also for technically competent supporting personnel and skilled craftsmen with a good working knowledge of the basic principles of mathematics and science. This group of supporting personnel and skilled craftsmen is making an increasingly greater contribution to the technical team, and is in critical demand wherever there is work in product development of a scientific or technical nature.

This bulletin and a companion publication, *Electronic Technology*, have been prepared to suggest post high school curriculums in the broad fields of electrical and electronic technologies. They are designed to illustrate types of full-time, 2-year preparatory programs which can provide certain basic education for entry jobs in these fields in support of engineers and scientific personnel, entrance into apprenticeship programs with the possibility of advanced standing, or other beginning work. They are not designed to prepare students for a specific job. They contain curriculums, course descriptions to develop the curriculums, and some suggested physical facilities layouts.

The courses in the first year—basic mathematics, science, electricity and electronics—and other subject matter—social science and language arts—are identical in both the electrical and electronic curriculums. Specialization, or branching into one technology field or the other, comes at the beginning of the second year in schools which may offer both curriculums concurrently.

The material in this bulletin should be helpful to administrators, supervisors, teacher trainers, and teachers in the promotion and development of new programs. It should also be useful as criteria for evaluating and upgrading existing technology curriculums. It should be recognized that the curriculum contained herein is a *suggested* curriculum. It must in most instances be adapted to meet local needs and preferences.

The technical materials in this bulletin were prepared by selected staff members of the Technical Institute Division of Oklahoma State University under a contractual arrangement between the University and the U.S. Office of Education. The social studies, communication skills, and shop processes courses were prepared by the staff of the Area Vocational Education Branch. All of the materials in this publication were under continuous discussion and review between the selected staff members of the university and the Area Vocational Education Branch. Many varied suggestions and criticisms were received by the branch from the university, consulting engineers, and other institutions and agencies which reviewed the material in draft form. Obviously, all views expressed could not possibly be incorporated into the final document. However, every suggestion received was carefully analyzed by all members of the branch staff and made part of the final document wherever possible. In view of this situation, it should not be inferred that the final curriculums are completely approved or endorsed by any one institution, agency, or person.

The technical accuracy of the curriculum materials is due largely to the work of a group of five outstanding electrical engineering leaders who thoroughly reviewed the materials. This review was followed by two days of intensive conference sessions with these engineers, the staff of the Area Vocational Education Branch and Mr. Maurice W. Roney, acting director of the Technical Institute Division and director of the School of Industrial Education of Oklahoma State University, Stillwater, Okla.

The final draft of this publication was prepared under the direction of Walter M. Arnold, director of the Area Vocational Education Branch, by members of the branch staff.

JAMES H. PEARSON
Assistant Commissioner for Vocational Education

Acknowledgments

THE U.S. Office of Education, Division of Vocational Education, recognizes the outstanding contributions of the following men who are members of prominent engineering and scientific associations and societies and have achieved recognition and distinction for their contributions to the field:

Stephen M. Batori, Controls and Communications Co., 1695 West 1st Avenue, Eugene, Oreg.

E. W. Boehne, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

William J. Burns, Manager of Mechanical Engineering, Long Island Lighting Co., 175 East Old Country Road, Hicksville, N.Y.

Joseph J. A. Jessel, Bureau of Power, Federal Power Commission, Washington, D.C.

George F. Maedel, President, RCA Institutes, 350 West 4th Street, New York, N.Y.

Maurice W. Roney, Acting Director, The Technical Institute, Oklahoma State University, Stillwater, Okla.

B. G. A. Skrotzki, Associate Editor, "Power," McGraw-Hill Publishing Co., Inc., 330 West 42d Street, New York 32, N.Y.

The U.S. Office of Education also acknowledges with appreciation the review of the materials and the constructive criticisms made by the administrators and staff members of the following institutions or agencies:

Wentworth Institute Boston, Mass.	H. Russell Beatty, President
Dunwoody Institute Minneapolis, Minn.	John Butler, Director
Western Michigan University Kalamazoo, Mich.	George E. Kohrman, Dean, School of Applied Arts and Studies
Washington State Board for Vocational Education Olympia, Wash.	Herman N. Miller, State Director of Vocational Education
Rochester Institute of Technology Rochester, N.Y.	Mark Ellingson, President
Connecticut State Board for Vocational Education Hartford, Conn.	Joseph T. Nerden, Chief, Bureau of Technical Institutes
Mohawk Valley Technical Institute Utica, N.Y.	Albert V. Payne, President
Southern Illinois University Division of Technical and Adult Education Carbondale, Ill.	Ernest J. Simon, Dean

California State Board for Vocational Education Sacramento, Calif.	Wesley P. Smith, State Director of Vocational Education
Erie County Technical Institute Buffalo, N.Y.	Laurence E. Spring, President
Milwaukee School of Engineering Milwaukee, Wis.	Karl O. Werwath, President
Del Mar Technical Institute Corpus Christi, Tex.	Everett R. Williams, Dean
Georgia State Board for Vocational Education Atlanta, Ga.	W. M. Hicks, Supervisor, Trade and Industrial Education
Ohio College of Applied Science Cincinnati, Ohio	G. Ross Henninger, President
Oregon State Board for Vacational Education Salem, Oreg.	W. G. Loomis, State Supervisor of Trade and Industrial Education

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A Suggested 2-Year Post High School Curriculum

Introduction

THE COURSES outlined in this curriculum guide have been arranged to provide optimum specialized technical instruction in a 2-year post high school program. The objective and the emphasis throughout is on an understanding of the engineering principles basic to the field of electrical power technology. The guide is organized for use in a system of education quite unlike that found in either the professional engineering school or in the traditional trade school. The curriculum is organized to provide a basic preparation for entry jobs in a variety of occupations in the field of electrical power distribution and in the design and manufacture of electrical equipment. The courses are arranged in workable sequence suitable to the instructional needs of students with an appropriate balance between technology courses, general education courses, and laboratory applications. It is not a pre-engineering curriculum.

A graduate of this program will have a good foundation in the principles of electrical power distribution technology and considerable facility with the "hardware" encountered in the industry.

To be most successful in the program of instruction, enrollees in the curriculum should have rated in the upper third of their high school graduating class. In some programs which have operated for a number of years, it has been found that a significant number of enrollees have been attracted to the program because of their interest in technical work and their inability financially, or for other reasons, to take the longer, more costly curriculums.

Ideally, the entrance requirements should include a year and a half of high school algebra, a year of geometry, a half year of trigonometry, and one year each of biology, chemistry, and physics. It is recognized, however, that many students will enter this program having had not more than 1 or 2 years of high school mathematics and science; and, that institutions establishing programs may have to temper entrance requirements in the light of the conditions existing in the service area from which students come, the graduation requirements of high schools in the area, and State requirements. It is not the purpose of this bulletin to elaborate on the subject of student recruitment and selection. It should be obvious even to the casual observer, however, that a comprehensive guidance and testing program is most desirable. The program is rigorous and will require carefully selected students and intensive effort on the part of students and instructors. It is also based on the assumption that students will have had a good basic general education by the time they enter this program. For that reason a minimum of general education subjects is included.

Essential to the success of any curriculum is a well-qualified instructional staff. Routine textbook instruction is entirely inadequate in technology programs. Instructors must be qualified to relate engineering principles to the industrial applications of such principles. Entrance requirements are high because time is too limited in a 2-year post high school program to provide all of the basic training in sciences and mathematics which should be prerequisites. Therefore, these disciplines must be taught in very close coordination with specialized course work.

To do this effectively the instructor must have three outstanding attributes: (1) technical competence, (2) industrial experience, and (3) professional acumen. An absolute minimum educational background for instructors should be graduation from a recognized technical institute, with additional study required for those who are to teach advanced courses. Industrial experience should include at least 2 years in the field of electrical technology, and all instructors should have professional training in the philosophy of technical education and teaching methods and procedures.

Graduates from this 2-year curriculum should be capable of performing some technical assignments in entry jobs in the field of electrical power distribution. These graduates should expect to continue their training in industry-sponsored programs as they gain experience on the job. Such special training programs are common throughout the industry and usually provide excellent opportunities for advancement.

The pattern of instruction outlined herein is based upon several years of experience in specialized training out of which some guidelines have been formulated to assist in curriculum planning. It cannot be too strongly emphasized, however, that adjustment to local physical facilities, industrial requirements, staff competencies, and other variables must be considered carefully, and high standards maintained.

Perhaps the most difficult decisions to be made in curriculum planning are those of placing time limits upon each unit of instruction. Time is of utmost importance in any 2-year technical program. Because of the broad requirements of the occupations in the field of electrical power distribution, it is difficult to select the material to be covered and to specify the units of laboratory and lecture. To persons unfamiliar with this type of instruction it often appears impossible to cover adequately the material contained in the curriculum in the time allotted. Careful coordination of laboratory and lecture is essential if the instructional objectives are to be accomplished within the time limits indicated for each course in this curriculum.

Flexibility is also extremely important in determining the relative emphasis to be placed upon laboratory and lecture in technical courses. It has been found to be most effective in programs of long standing for both the lecture and the laboratory work in a given course to be the responsibility of a single individual. Since complete coordination of lecture and laboratory is nearly impossible where separate instructors are used for laboratory and for lecture, it is essential that much of the theory be taught or at least reemphasized in the laboratory. Where a single individual covers both phases of the instruction, the laboratory time can be utilized, wherever necessary, to supplement and extend theoretical concepts, while at the same time used to animate and substantiate these concepts.

The laboratory time shown for certain courses of this curriculum has been extended to accomplish this purpose. The aim is not to use the laboratory time for lecture, but rather to provide as much time as possible for discussion, both formal and informal, of the actual material being studied. In the discussion on mathematics and science found immediately following the curriculum synopsis, developing mathematics and science concepts is treated in greater detail. It is sufficient for this discussion to emphasize that the laboratory work in the first stages of the program may involve application of mathematical concepts that are quite new to the students. When this is the situation, the laboratory may be devoted almost entirely to mathematics applications built around laboratory experiments. Because this approach may often be necessary, it is obvious that in order to use laboratory time for group instruction, laboratories should include both demonstration and lecture areas. Ideally, these facilities should be arranged to permit group instruction without requiring students to leave their work areas. To the degree that local physical facilities will not lend themselves to this method of presentation, the curriculum will have to be adapted to fit the facilities that do exist, and another procedure developed for coordinating concept presentation with practical application in the laboratory without at the same time sacrificing quality or compromising standards.

The course outlines which follow are short and descriptive. The individual instructor will have to prepare complete courses of study and arrange the curriculum material in psychological order before starting instruction. Sample instructional sheets found in the Appendix may be helpful to instructors in preparing units of instruction.

Surveys indicate that familiarity with technical report writing and industrial relations are important in certain technical work. Provision is made in this curriculum for these subjects through the social studies and communication skills courses. A sample report and a guide for making written reports may also be found in the Appendix. Because the success of any technical training program will depend in large measure on adequate equipment and laboratory facilities, some suggested layouts are included in the Appendix.

In short, the material in this bulletin is not offered to be applied to a given situation exactly as outlined. It is presented to illustrate how an electrical power technology training program can be organized. It provides a suggested framework within which such training may be developed.

Electrical Technology Curriculum

First Year

First Semester

		Class	Lab.	Total	Page
ER 114	Technical Mathematics I (Algebra and Trigonometry)	4	0	4	9
ER 115	Direct Current Circuits and Machines	3	6	9	11
G 113	Social Science	3	0	3	14
G 123	Technical Drawing	1	6	7	17
G 133	Communication Skills	3	0	3	20
	Subtotal	14	12	26	

Second Semester

		Class	Lab.	Total	Page
ER 164	Technical Mathematics II (Applied Analytical Geometry and Calculus)	4	0	4	22
ER 185	Time Varying Circuits	3	6	9	24
ER 165	Basic Electronics	3	6	9	27
G 111	Shop Processes	1	2	3	33
G 161	Technical Report Writing	1	0	1	36
G 162	Graphic Analysis	1	3	4	38
	Subtotal	13	17	30	

Second Year

Third Semester

		Class	Lab.	Total	Page
G 204	Engineering Science	3	3	6	41
E 213	Electrical Instruments and Measurements	2	3	5	45
E 215	Alternating Current Machines	3	6	9	48
E 272	Electrical Installation Planning	2	0	2	52
G 213	Chemistry and Applications in Electricity	2	3	5	54
	Subtotal	12	15	27	

Fourth Semester

		Class	Lab.	Total	Page
E 264	Industrial Electronics	3	3	6	58
E 274	Electrical Control Circuits	3	3	6	60
E 284	Electrical Power Systems—In-Plant Distribution (With Utility Systems Option)	3	3	6	63
E 294	Operating Problem Analysis	2	6	8	68
	Subtotal	11	15	26	
	GRAND TOTAL	50	59	109	

Course letters:

ER—Technical specialized courses common to Electronic and Electrical curriculums
G—General and related courses
E—Technical Electrical Courses

Curriculum Synopsis

About the Curriculum

EXTENSIVE PLANNING was given to the arrangement and emphasis on subject matter areas included in this curriculum. The suggested scope and sequence of the courses in the curriculum which is outlined on the preceding page are designed to develop concepts in a spiral of increasing complexity or difficulty. As each new concept or area of knowledge is formally presented, it is given practical application of increasing depth as the concept is built upon by each succeeding technical course in the curriculum. In other words, subject matter areas or concepts are presented both on a unit basis as they are in the traditional curriculum, and as part of applications in laboratory experiences and other courses. Once introduced a concept is never dropped, but rather it is extended and applied with increasing complexity by feedback principles in correlation with each new concept introduced in subsequent courses. This is particularly true in the introduction and development of mathematics and science knowledges. Mathematics and science are an integral part of each technical course in the curriculum.

Mathematics and the physical sciences are key disciplines in all technical study. The traditional approach in providing the requisite facility with these tools of learning is to concentrate them in the first phases of the training program. With this system the technical study must necessarily be deferred to the latter stages of curriculum. In a 2-year post high school program this kind of arrangement is impractical. Deferring the technical study, even for one term, imposes serious limitations on the total curriculum. The alternative approach and the one used in this curriculum provides an integration of mathematics and selected physical sciences with basic electrical physics and electrical circuits. This method has the added advantage of being a great deal more interesting to the student than the traditional academic sequential treatment of subject matter concepts.

In treating mathematics and science as an integral part of the program a high degree of coordination is required. This coordination involves the teaching of mathematics by application in technical courses concurrent with formal instruction in mathematics classes. This is in sharp contrast to the sequential course system and has certain distinct advantages over the latter in a 2-year program. An example of such correlation is found by an analysis of the following courses:

In the first semester:

ER 114 *Technical Mathematics I*, concurrent with
ER 115 *D. C. Circuits*

In the second semester:

ER 164 *Technical Mathematics II*, concurrent with
ER 185 *Time Varying Circuits*, and
ER 165 *Basic Electronics*

By devoting a major part of the laboratory time in the circuit courses to mathematics analysis, a highly effective integration is achieved. With the additional outside study requirement (2 hours for each class hour) the basic mathematics needs of the student can be provided without deferring his introduction to the specialized subject. The net result of this two-semester study program is a total of 23 semester hours of study devoted to mathematics, basic electrical physics, and circuits. The curriculum is balanced by 13 semester hours of related technical and general subjects.

It should be recognized that this system requires instructional personnel with well-defined competencies in both technical principles and mathematics. Interdisciplinary feedback is essential for the success of the system. It is an established fact that the system is inherently sound and workable. It will attract and hold competent students by being at the same time interesting and challenging. The first two semesters of the curriculum outlined here will provide a solid base of electrical knowledge on which to build the advanced course instruction. The subsequent study can and should be circuit-based rather than equipment-based, *requiring a continuation and extension of mathematical analysis, including a significant amount of "handbook" design.* When complex electrical and electronics equipment is utilized for instruction, those special circuit applications that make the equipment unique can be studied separately. This then becomes the heart of the study program—broad applications of basic principles well learned through mathematical analysis.

The curriculum outlined herein has had intensive review by representatives of industry and by educators in the field. It is the product of the pooled suggestions of a large number of people, and represents somewhat the middle ground of the recommendations which have been received. It brings together the best features of time-tested 2-year post-high school curriculums, and the suggestions made by industry into a program which will serve the purposes to be accomplished by title VIII of the National Defense Education Act of 1958. Students who complete this basic education and who then gain experience and further specific training will be equipped to give the engineer or scientist the technical assistance he needs in his engineering or scientific work, or will be able to fulfill the requirements of other technical occupations.

This curriculum guide indicates the scope, or breadth, of the concepts to be introduced and a suggested sequence into which these concepts can be arranged. It contains outlines of the courses to be presented. The job of preparing course instructional materials, teaching guides, units of instruction, and making the curriculum fit local needs and conditions is the job of the instructional staff of the school which will utilize the curriculum. In short, the individual laboratory or classroom teacher with competent and expert advice, will make the final determination of the actual units of instruction, the time to be spent on each topic, which textbooks and references to use, and what supplementary materials will be necessary to develop the best learning situation for a given course.

The curriculum can only suggest those areas of information which should be covered to give students a fund of scientific knowledges which will enable them to perform at a level of competency in entry positions in industry which will be expected of them upon completion of the program of studies. The instructor must determine the learning situations which will give proper application to the concepts outlined in this curriculum. He should seek the assistance of a representative local advisory committee with both labor and management, other faculty members, local supervisors and administrators and consultants, all of whom can help him in developing courses of study for the curriculum, and in determining local adaptations to meet the needs and desires of industry.

Although "safety" is not designated as a special subject matter area in the outline of courses, it is an indispensable part of each learning experience. Laboratory exercises should stress the accident potential of each application and the preventative measures to be taken to protect against possible injury. Safety is actually a "philosophy," for it is directly related to the manner in which a person performs, functions or exposes himself to possible injury and the attitude he has toward the objects or materials with which he works. It is almost impossible to "teach" good safety. Safety is part of a way of life. Proper safe practices will grow out of desirable personal values, attitudes, and procedures in the use of materials or objects. A student must be taught to perform each function of his job safely.

Too much emphasis cannot be placed upon the need for technically trained people to be able to communicate data and ideas clearly and effectively. Basic courses in communication are included in the curriculum to give students refresher work as well as exercises in functional English. As with mathematics and science concepts, there is practical application of proper usage of English in all courses. All laboratory reports and written assignments should be corrected for grammar and for proper writing and reporting procedures.

The list of suggested texts and references includes only those books or reference materials known to be utilized in one or more successful training programs. In all probability there are many other very fine texts or references in each of the subject matter fields being used by training programs but not known to the persons who reviewed these curriculums and prepared the course outlines. The lists for each course do not attempt to cover the field and are by no means complete.

In summary, this curriculum is the product of the efforts of a large number of people—educators, engineers, university and institute directors, and Office of Education staff. It is a suggested outline of learning experiences considered a necessary part of the training of electrical technicians to support engineers and scientists. It should not be taken literally and imposed upon a community but rather used as a guide in developing a curriculum which is best suited for a given situation, and one which will meet the national defense needs for occupations in this field of work.

COURSE OUTLINES: FIRST YEAR, FIRST SEMESTER

ER 114, Technical Mathematics I (Algebra and Trigonometry)

Hours Required

Class, 4; Laboratory, 0

Description

Review of algebra, geometry, and the fundamental concepts of trigonometry; use of tables; solution of right triangles; law of sines and law of cosines; special products and factoring; simultaneous equations; exponents and radicals; quadratic equations; logarithms; vector algebra including complex quantities and "j" operator. Emphasis on the application of mathematics to problems in electricity and electronics.

Note: In order to cover adequately the material outlined in this course it is necessary to coordinate the instruction with the course and laboratory work in ER 115, *Direct Current Circuits and Machines.* Laboratory time in that course includes extensive mathematical computation.

Major Divisions

		Class hours
I.	Basic Algebra	8
II.	Polynomials	8
III.	Algebraic Exponents	8
IV.	Quadratic Equations	12
V.	Miscellaneous Mathematics	3
VI.	Logarithms	8
VII.	Trigonometry of Right Triangles	8
VIII.	Vectors	10
IX.	Vector Algebra	10

Division I. Basic Algebra—8 hours

1. Literal and explicit numbers
2. Algebraic expressions
3. Algebraic fractions
4. Equation with one unknown

Division II. Polynomials—8 hours

1. Two unknowns
2. More than two unknowns
3. Graphical solutions
4. Determinants

Division III. Algebraic Exponents—8 hours

1. Laws of exponents
2. Fractional exponents
3. Reduction of exponents
4. Multiplication and division of exponents

Division IV. Quadratic Equations—12 hours

1. True equations
2. Incomplete equations
3. Formula solution
4. Extraneous roots
5. Vanishing roots
6. Equations with radicals
7. Simultaneous solution
8. Solution by determinants
9. Graphical solution
10. Reduction of forms

Division V. Miscellaneous Mathematics—3 hours

1. Ratio
2. Proportion
3. Variations of equations

Division VI. Logarithms—8 hours

1. Nature of logarithms
2. Application of logarithms
3. Different bases of logarithms
4. Application and use of logarithms

Division VII. Trigonometry of Right Triangles—8 hours

1. Basic trigonometric functions
2. Functions of angles in all quadrants
3. Special angles—0°, 30°, 45°, 60°, 90°, ... 360°
4. Some identities
5. Right triangle laws
6. Laws of sine and cosine

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7. The inverse functions
8. Use of trigonometric tables
9. Applications of trigonometric functions

DIVISION VIII. Vectors—10 hours

1. Vector representation of quantities
2. Positive and negative quantities
3. Angular motion and the four quadrants

DIVISION IX. Vector Algebra—10 hours

1. Graphic trigonometric functions
2. Averages of sine and sine² waves
3. Phase relationships
4. Complex notation, vector addition and subtraction
5. Multiplication and division of vectors
6. Conversion of complex to polar forms

Texts and References

Select one or more books from the following list for texts. Others may be used as reference books.

COOKE, NELSON M., *Mathematics for Electricians and Radiomen.* New York; McGraw-Hill Book Co.

KEASBY, MILES A., KLINE, GEORGE A. *and* MCILHATTEN, DAVID A., *Engineering Mathematics,* New York; The Blakiston Co.

RICE, HAROLD S. *and* KNIGHT, R. M., *Technical Mathematics with Calculus.* New York; McGraw-Hill Book Co.

RICHARDSON, M., *Fundamentals of Mathematics,* New York; The Macmillan Co.

RICHMOND, O. E., *Calculus for Electronics.* New York; McGraw-Hill Book Co.

SINGER, BERTRAND B., *Basic Mathematics for Electricity Radio and TV.* New York; McGraw-Hill Book Co.

ER 115, Direct Current Circuits and Machines

Hours Required

Class, 3; Laboratory, 6

Description

Basic physics of the electron, electric units, and Ohm's law. Resistance combinations. Meter connections. Magnetism and magnetic circuits. Electric power. Characteristics of electric conductors. Inductance and capacitance. Direct current generators, motors and controls. Use of common measuring and metering equipment.

Note. Much of the laboratory time in this course is devoted to mathematical computation, including the use of the slide rule. Mathematical usage should parallel as closely as possible the material covered in ER 114, Technical Mathematics I.

Major Divisions

	Class hours	*Laboratory hours*
I. Units	6	12
II. Series Circuits	6	12
III. Parallel Circuits	3	6
IV. Combination Circuits	3	6
V. Circuit Laws	3	6
VI. Electro-Chemical	3	6
VII. Conductors and Insulators	3	6
VIII. Magnetism	7	15
IX. Electro-Capacitance	7	15
X. Electrical Machines	6	6
XI. Generator and Motor Testing	4	12

Division I. Units

A. Units of instruction—6 hours
1. Introduction of laboratory rules, grading, etc.
2. Electrical units
   a. Electron theory—understanding of direction of current flow
   b. Volts
   c. Amperes
   d. Ohms
   e. Watts
   f. Prefixes to units (milli-mega, absolute values)
   g. Use of voltmeters, ammeter, and Ohm meter

B. Laboratory projects—12 hours
1. Safety and artificial respiration
2. Slide rule (C & D & CI scales)

Division II. Series Circuits

A. Units of instruction—6 hours
1. Ohm's law
2. The series circuit
3. Conductance of series circuit
4. Voltage drops of lines
5. Voltage by proportion

B. Laboratory projects—12 hours
1. Ohm's law
2. Series circuit
3. Voltage by proportion
4. Problems on Ohm's law
5. Slide rule
   a. Scales CF & DF
   b. Scales AB–K

Division III. Parallel Circuits

A. Units of instruction—3 hours
1. Equivalent resistances
2. Law of division of current in parallel circuit

B. Laboratory projects—6 hours
1. Parallel circuit
2. Selected problems

Division IV. Combination Circuits

A. Units of instruction—3 hours
1. Reduction of combination circuits
2. Solution of combination circuits

B. Laboratory projects—6 hours
Combination circuits

DIVISION V. Circuit Laws
- A. Units of instruction—3 hours
  - 1. Superposition law
  - 2. Kirchhoff's law
    - a. Mesh current method
    - b. Nodal current method
- B. Laboratory projects—6 hours
  - 1. Kirchhoff's law
  - 2. Superposition law

DIVISION VI. Electro-Chemical
- A. Units of instruction—3 hours
  - 1. Batteries—types
    - a. Primary
    - b. Secondary
    - c. Capacity
    - d. Charging
  - 2. Electroplating
  - 3. Fuel cells
- B. Laboratory projects—6 hours
  - 1. Battery construction
  - 2. Battery charging

DIVISION VII. Conductors and Insulators
- A. Units of instruction—3 hours
  - 1. Conductors and insulators
    - a. Materials
    - b. Conductivity
    - c. Sizes
    - d. Methods of construction
    - e. Resistance
    - f. Current carrying capacity and insulation (electrical and thermal)
- B. Laboratory projects—6 hours
  Identification, size and measurement, circular-mil resistance

DIVISION VIII. Magnetism
- A. Units of instruction—7 hours
  - 1. Permanent magnets
  - 2. Magnetic units
    - a. Forces between current-carrying conductors and between such conductors and magnetic fields
    - b. Eddy currents
    - c. Magnetic damping
  - 3. Electro-magnet construction and use
  - 4. Magnetic law (comparable to Ohm's law for circuits)
  - 5. Electro-inductors
  - 6. Magnetic coupling
  - 7. Types of inductances
  - 8. LR time constants
- B. Laboratory projects—15 hours
  - 1. Permanent magnets
  - 2. Electro-magnets
  - 3. Magnetic coupling
  - 4. LR time constants

DIVISION IX. Electro-Capacitance
- A. Units of instruction—7 hours
  - 1. Electro-statics
  - 2. Capacitance laws and units
  - 3. Types of capacitors
  - 4. Measurement of capacitance
  - 5. RC time constants
  - 6. Series-parallel capacitors
  - 7. Voltage rating of capacitors
- B. Laboratory projects—15 hours
  - 1. Capacitor types
  - 2. Series and parallel capacitors
  - 3. RC time constants

DIVISION X. Electrical Machines
- A. Units of instruction—6 hours
  - 1. Generators
    - a. Generation of E.M.F.
    - b. Type windings of a generator
      - (1) Ring
      - (2) Drum
      - (3) Lap
    - c. Types of generators
      - (1) Series
      - (2) Shunt
      - (3) Compound
  - 2. Motors
    - a. Motor action
    - b. Generator counter E.M.F.
    - c. Types of motors
      - (1) Series
      - (2) Shunt
      - (3) Compound
- B. Laboratory projects—6 hours
  - 1. Generation
  - 2. Voltage regulation efficiency

DIVISION XI. Generator and Motor Testing
- A. Units of instruction—4 hours
  - 1. Voltage regulation of generator
  - 2. Efficiency of generator
  - 3. Heat of a generator
  - 4. Motor performance
  - 5. Speed regulation of motor
  - 6. Efficiency of motors
  - 7. Heat of motor
    - a. Commutation
    - b. Air gap

B. Laboratory projects—12 hours
   1. Motor load—test on dynamometer
   2. Motor load test—on prony brake
   3. Motor temperature rise experiment

Texts and References

Select one of the following as a text. Others are to be considered as possible reference books.

DAWES, CHESTER L., *A Course in Electrical Engineering Vol. I.* New York: McGraw-Hill Book Co.

GRAHAM, KENNARD C., MCDOUGAL, W. L., RANSON, R. R., *and* DUNLAP, C. H., *Fundamentals of Electricity.* Chicago: American Technical Society.

JACKSON, HERBERT M., *Introduction to Electric Circuits.* Englewood Cliffs, N.J.: Prentice-Hall.

VAN VALKENBURGH, NOOGER *and* NEVILLE, INC., *Basic Electricity, Vol. 2, Direct Current Circuits, Ohm's and Kirchhoff's Laws; Electric Power.* New York: John F. Rider, Publisher, Inc.

G 113, Social Science

Hours Required

Class, 3; Laboratory, 0

Description

The course is oriented to the proposition that each technician in a democracy has a responsibility to make a productive contribution toward the perfection and perpetuation of the American way of life; and, that to do so, he must know and understand his responsibilities and obligations to himself, his family, his community, his State and Nation, and the world. The salient elements of the four basic social sciences (psychology, sociology, economics, and government) are reviewed to help the student achieve a good working understanding of his total environment and the forces which interact to form the social setting in which he works and lives. Time allotments to the various elements within major divisions will depend upon the background of the class.

Major Divisions

	Class hours
I. General Psychology	8
II. Sociology	8
III. Economics	24
IV. American Government	8

DIVISION I. General Psychology

A. Basic human drives and motives
B. Heredity and environment
C. Psychology of decision making
D. Group dynamics
   1. Conditions affecting group morale
   2. Forming opinions
E. Human relations
F. Principles of learning

DIVISION II. Sociology

A. Our culture, its improvement and perpetuation
B. Relationship of individuals to social institutions
   1. Home
   2. Public and private educational institutions
   3. The community
   4. Church
   5. Organized social groups—fraternal, labor, business, and professional
   6. Government
   7. Other
C. Forces of social disorganization, such as migration, crime, mobility, subversive groups, etc.

DIVISION III. Economics

A. Social, political and economic forces responsible for the growth and development of industry and technology
   1. Pastoral stage
   2. Handicraft stage
   3. Machine stage
   4. Atomic stage
   5. Planned economy or laissez faire
B. Economic expressions
   1. Land, resources (human and natural) capital, management, and labor
   2. Economic goods
   3. Economic wealth
   4. Utility
   5. Other
C. Comparative economic systems
   1. Capitalism—free enterprise
   2. Socialism
   3. Communism
   4. Other
D. Labor problems and legislation
   1. Union policies and practices
      a. Wages, hours
      b. Closed shop

c. Union shop
d. Seniority
e. Worker relationships
f. Worker benefits—sickness, accident, other
2. Industrial strife
a. Strikes
b. Boycott, lockout, slow down, sabotage, picketing
c. Mediation
3. Labor legislation
a. Taft-Hartley law
b. Labor-Management Reporting and Disclosure Act of 1959
c. NLRB
d. Wage-hour board
e. Safety legislation
f. Minimum-wage law
g. Fair Employment Practices Acts

E. Business law and management
1. Types of organizations and legal aspects
a. Single ownership
b. Partnership
c. Corporation
d. Trusts and holding companies
e. Security and commodity exchanges
f. Public utilities
g. Marketing co-ops
h. Chattels and real estate
i. Savings and loan associations
2. Our capitalistic system—private enterprises
a. Trust laws
b. Monopolies, franchises, fair trade
c. Banks and banking
(1) Bank insurance
(2) Discounting and loans
d. National income—sources
e. Gross national product
f. Personal income
g. Public debt—limits
h. Private debt—limits
i. Government grading and quality controls
3. Finance, investment and taxation
a. Investments and securities
b. Stocks and bonds
c. Monetary system
Coins, currency, legal tender, Federal Reserve System, fiat money, etc.
d. Credit buying—effects of interest rate
e. Taxation
(1) Income taxes
(2) Personal and real property taxes—assessment, evaluation, equalization, etc.
(3) Corporation taxes
(4) Capitation taxes
(5) Inheritance taxes
(6) Theories of shifting and incidence in taxation
(7) Sales tax
(8) Other
f. Insurance

DIVISION IV. American Government

A. Constitutional bases for Federal, State, and local governmental relationships
1. Federation—confederation
2. Compact of States theory

B. Political parties and pressure groups
1. Nominating conventions and election campaigns
2. Party discipline
3. Lobbies and vested interest groups
4. Other

C. Organization and function of legislative branch
1. Minority and majority floor leaders
2. Whip
3. Committee organizations
4. Other

D. The organization and function of executive branch
1. Cabinet
2. Executive staff and assistants

E. The court system
1. Federal courts
a. District
b. Appellate
c. Supreme
d. Special
2. State courts
3. Civil suits or actions
4. Criminal actions

F. Responsibilities of citizens in a democracy
1. Understanding propaganda
2. Becoming informed on public affairs
3. Voting
4. Running for office, etc.
5. Public welfare

G. International relations and world problems
1. United Nations

2. Treaties
3. Mutual security pacts or agreements
4. Alliances
5. Current events
6. Technical assistance, such as mutual aids in economics, agriculture, education, etc.

Texts and References

Select one of the following as a text for appropriate social science area being studied. Others may be considered as possible reference books.

ALILUNAS, LEO J., *Youth Faces American Citizenship.* Chicago: Lippincott.

AMISS, JOHN, *Economics.* Chicago: American Technical Society.

BERNHARDT, KARL S., *Practical Psychology.* New York: McGraw-Hill Book Co.

BIERSTEDT, R., *The Social Order.* New York: McGraw-Hill Book Co.

BLODGETT, RALPH H. and KEMMERER, DONALD L., *Comparative Economic Development.* New York: McGraw-Hill Book Co.

BONE, HUGH A., *American Politics and the Party System.* New York: McGraw-Hill Book Co.

BORGARDUS, EMORY S. and LEWIS, ROBERT H., *Social Life and Personality.* New York: Silver Burdett Publishing Co.

BRUER, J. M., *All About Me.* Chicago: American Technical Society.

DODD, JAMES H., Applied Economics; *Elementary Principles of Economics Applied to Everyday Problems.* Cincinnati, Ohio: South-Western Publishing Co.

FOSTER, CHARLES R., *Psychology for Life Adjustment.* Chicago: American Technical Society.

GAVIN, RUTH W., GRAY A. A., and GROVES, ERNEST, *Our Changing Social Order.* Boston: D. C. Heath Publishing Co.

HAAS, ERNEST B. and WHITING, ALLEN S., *Dynamics of International Relations.* New York: McGraw-Hill Book Co.

JOHNSON, DONALD M., *Essentials of Psychology.* New York: McGraw-Hill Book Co.

MAGRUDER, FRANK A., *American Government.* New York: Allyn & Bacon Publishing Co.

MORGAN, CLIFFORD T., *Introduction to Psychology.* New York: McGraw-Hill Book Co.

MUELLER, O. F. W., Jr., *Money and Banking.* New York: McGraw-Hill Book Co.

MUSGRAVE, RICHARD A., *The Theory of Public Finance.* Johns Hopkins University. New York: McGraw-Hill Book Co.

MCCARTHY, JOHN A., *Rights of the American Worker.* Chicago: American Technical Society.

SCHNEIDER, EUGENE V., *Industrial Sociology.* New York: McGraw-Hill Book Co.

SELEKMAN, BENJAMIN M., *Labor Relations and Human Relations.* New York: McGraw-Hill Book Co.

STEINER, GEORGE A., *Government's Role in Economic Life.* New York: McGraw-Hill Book Co.

YOUNG, DALLAS M., *Understanding Your Labor Problems.* New York: McGraw-Hill Book Co.

C 123, Technical Drawing

Hours Required

Class, 1; Laboratory, 6

Description

An elementary course designed for students having limited drawing experience. Use of templates, including lettering templates; fundamentals of drawing and drafting room practices; electrical circuit drawing, terms, symbols and standards. All symbols used are those established by the U.S. Bureau of Standards. Students are cautioned that adaptation of standard symbols to special symbols used by future employers may be necessary. Emphasis is placed on construction and interpretation of typical industrial drawings.

Major Divisions

	Class hours	*Laboratory hours*
I. Fundamentals	2	12
II. Shape Description	3	18
III. Dimensioning Drawings	2	12
IV. Pictorial Drawings	2	12
V. Threads and Fasteners	1	6
VI. Working Drawings	2	12
VII. Electrical Circuits	3	18
VIII. Electrical Layouts and Equipment	2	12

DIVISION I. Fundamentals

A. Units of instruction—2 hours
  1. Mechanical drawing equipment
     a. Use and care
     b. Special electrical symbol templates
     c. Alphabet of lines
  2. Sheet layouts
     a. Papers, sizes, and border lines
     b. Nameplate, blocks, and scales
     c. Centering and procedure
  3. Lettering
     a. Types of alphabets
     b. Freehand techniques
     c. Use of lettering templates
  4. Elementary geometrical constructions

B. Laboratory projects—12 hours
  1. Construction of geometrical designs using instruments. Emphasis on neatness and line technique
  2. Freehand lettering exercises stressing simplicity of style and ease of reading
  3. Lettering exercises providing practice in the use of lettering instruments

DIVISION II. Technical Sketching and Shape Description

A. Units of instruction—3 hours
  1. Techniques of freehand sketching
     a. Measuring subject
     b. Blocking drawing, and proportions
     c. Detailing
  2. Theory of projection
     a. Isometric
     b. Oblique
     c. Sketching
  3. Multiview drawing
     a. Principles of multiview drawing
     b. Relationship of views
     c. Selection of views
     d. Treatment of invisible surfaces and center lines
     e. Auxiliary views
  4. Sectional views
     a. Types and purposes
     b. Symbolic lines
     c. Half sections and broken sections
     d. Full sections

B. Laboratory projects—18 hours
  1. Freehand sketches of simple machine parts. Designed to develop skill in estimating distances, controlling proportions, and in the use of freehand techniques for constructing geometrical figures.

2. Missing-line and missing-view exercises to provide practice in multiview projection.
3. Scale drawings of machine parts including a requirement for sectional views.

DIVISION III. Dimensioning Drawings

A. Units of instruction—2 hours
  1. General dimensioning
     a. Size and location dimensions
     b. Fractional and decimal dimensioning
     c. Do's and don'ts of dimensioning
     d. Procedure in dimensioning
  2. Formulation and placement of shop notes
     a. Purpose of notes
     b. Shop terms of processor
     c. How to make measurements of shop operations
  3. Tolerancing
     a. Purpose
     b. Terminology
     c. Classes of fits

B. Laboratory projects—12 hours
  1. Construction of multiview drawings of machine parts requiring simple dimensions and shop notes
  2. Construction of multiview drawings of more complex machine parts requiring decimal dimensioning and determining and indicating tolerances.

DIVISION IV. Pictorial Drawing

A. Units of Instruction--2 hours
  1. Isometric drawing
     a. Position of axes
     b. Non-isometric lines
     c. Steps in construction
     d. 4-center method of constructing ellipses
     e. Advantages and disadvantages
  2. Oblique drawing
     a. Choice of positions of axes
     b. Steps in construction
     c. Methods of reducing distortion
     d. Advantages and disadvantages
  3. Perspective
     a. General principles
     b. One-point
     c. Two-point
     d. Advantages and disadvantages
  4. Shading
     a. Shade lines
     b. Surface shading with lines
     c. Smudge shading
     d. Stippling

B. Laboratory projects—12 hours
  1. Isometric drawings of a transformer or other electrical equipment stressing correct projection and position of axes. Require suitable shading.
  2. Oblique drawing of similar material. Requires suitable shading.
  3. Perspective drawing of a small building. Use either one- or two-point perspective.

DIVISION V. Threads and Fasteners

A. Units of instruction—1 hour
  1. Screw thread types and nomenclature
     a. Nomenclature of threads
     b. Types of threads
     c. Drawing and specifying threads
  2. Representation of threads
     a. Detailed
     b. Schematic
     c. Simplified
  3. Fastener representations
     a. Bolts and nuts
     b. Screws
     c. Springs
     d. Rivets
     e. Keys
  4. Identification symbols for specifications
     a. Use of simplified drawings
     b. Specifications and loads of fasteners

B. Laboratory projects—6 hours
  Drawings requiring representations of threads in the schematic and simplified forms and including the necessary dimensioning.

DIVISION VI. Working Drawings

A. Units of instruction—2 hours
  1. Detail drawings
     a. Construction and purpose
     b. Title and record strips
  2. Assembly drawings
     a. Types and uses
     b. Parts lists
     c. Sectioning practices

B. Laboratory projects—12 hours
  1. An assembly drawing of a simple machine. Provides practice in the drawing of assemblies and sectioning procedures.
  2. A pictorial assembly drawing providing practice in pictorial construction and shading.

DIVISION VII. Electrical Circuits

A. Units of instruction—3 hours
   1. Electrical symbols
      a. Electronic symbols
      b. Power symbols
      c. Architectural symbols
      d. Symbol guides
      e. Relay nomenclature
   2. Schematic diagrams
      a. Schematic layouts
      b. One-line diagrams
   3. Wiring diagrams
      a. Industrial buildings
      b. Power plants
      c. Industrial controls
      d. Communication circuits

B. Laboratory projects—18 hours
   1. Symbols
   2. Schematic diagram of radio receiver
   3. Electronic industrial control

DIVISION VIII. Electrical Layouts and Equipment

A. Units of instruction—2 hours
   1. Layouts
      a. Chassis layouts
      b. Panel layouts
      c. Switchboard layouts
      d. Laboratory layout
   2. Electric equipment
      a. Multiview drawings
      b. Pictorial drawings
      c. Sections
      d. Details

B. Laboratory projects—12 hours
   1. Make a layout for an electronics chassis and panel
   2. Make a multiview and pictorial view of one of the following:
      a. Transmitter in rack
      b. Metalclad switchboard
      c. Motor-generator set
      d. Amplidyne generator

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BAER, CHARLES J., *Electrical and Electronic Drawing*. New York. McGraw-Hill Book Co.

BISHOP, COLVIN E., *Electric Drafting and Design*. New York. McGraw-Hill Book Co.

FRENCH, T. E., *and* VIERCK, C. J., *Graphic Science*. New York. McGraw-Hill Book Co.

GIESECKE, FREDERICK E., MITCHELL, ALVA, *and* SPENCER, HENRY C., *Technical Drawing*. New York. The Macmillan Co.

HEINE, GILBERT M., and others, *How To Read Electrical Blueprints*. Chicago. American Technical Society.

KOCHER, STANLEY E., *Electrical Drafting*. Scranton, Pa. International Textbook Co.

LUZADDER, WARREN J., *Graphics for Engineers*. Englewood Cliffs, N.J. Prentice-Hall Book Co.

LUZADDER, WARREN J., *Fundamentals of Engineering Drawing*. Englewood Cliffs, N.J. Prentice-Hall Book Co.

SPENCER, H. C., *Basic Technical Drawing*. New York. The Macmillan Co.

G 133, Communication Skills

Hours Required

Class, 3; Laboratory, 0

Description

Course is prerequisite to Technical Report Writing, G 161, and places emphasis throughout on exercises in writing, speaking, and listening. Analysis is made of each student's strengths and weaknesses. The pattern of instruction is geared principally to helping students improve skills in areas where common weaknesses are found. The time allotments for the various elements within major divisions will depend upon the background of the class.

Major Divisions

	Class hours
I. Sentence Structure	6
II. Using Resource Materials	4
III. Written Expression	20
IV. Talking and Listening	12
V. Improving Reading Efficiency	6

DIVISION I. Sentence Structure

A. Diagnostic test
B. Review of basic parts of speech
C. What makes complete sentences
D. Use and placement of modifiers, phrases, and clauses
E. Sentence conciseness
F. Exercises in sentence structure

DIVISION II. Using Resource Materials

A. Orientation in use of school library
   1. Location of reference materials, *Readers Guide*, etc.
   2. Mechanics for effective use
   3. Dewey Decimal System
B. Dictionaries
   1. Types of dictionaries
   2. How to use dictionaries
   3. Diacritical markings and accent marks
C. Other reference sources
   1. Technical manuals and pamphlets
   2. Bibliographies
   3. Periodicals
   4. *Industrial Arts Index*
D. Exercises in use of resource materials
   1. *Readers Guide*
   2. Atlases
   3. Encyclopedias
   4. Other

DIVISION III: Written Expression (emphasis on student exercises)

A. Diagnostic test
B. Paragraphs
   1. Development
   2. Topic sentence
   3. Unity and coherence
C. Types of expression
   1. Inductive and deductive reasoning
   2. Figures of speech
   3. Analogies
   4. Syllogisms
   5. Cause and effect
   6. Other
D. Written exercises in paragraphs
E. Descriptive reporting
   1. Organization and planning
   2. Emphasis on sequence, continuity, and delimitation to pertinent data or information
F. Letter writing
   1. Business letters
   2. Personal letters
G. Mechanics
   1. Capitalization
   2. Punctuation—when to use:
      a. Period, question mark, and exclamation point
      b. Comma
      c. Semicolon
      d. Colon
      e. Dash
      f. Parentheses
      g. Apostrophe

3. Spelling
   a. Word division—syllabication
   b. Prefixes and suffixes
   c. Word analysis and meaning—context clues, phonetics, etc.

H. Exercises in mechanics of written expression

DIVISION IV. Talking and Listening (emphasis on student exercises)

A. Diagnostic testing
B. Organization of topics or subject
C. Directness in speaking
D. Gesticulation and use of objects to illustrate
E. Conversation courtesies
F. Listening faults
G. Taking notes
H. Understanding words through context clues
I. Exercises in talking and listening

DIVISION V. Improving Reading Efficiency

A. Diagnostic test
B. Reading habits
   1. Correct reading posture
   2. Light sources and intensity
   3. Developing proper eye span and movement
   4. Scanning
   5. Topic sentence reading
C. Footnotes, index, bibliography, cross references, etc.
D. Techniques of summary
   1. Outline
   2. Digest or brief
   3. Critique
E. Exercise in reading improvement
   1. Reading for speed
   2. Reading for comprehension

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BAIRD, A. CRAIG and KNOWER, FRANKLIN H., *Essentials of General Speech.* New York: McGraw-Hill Book Co.

BAIRD, A. CRAIG and KNOWER, FRANKLIN H., *General Speech; An Introduction.* New York: McGraw-Hill Book Co.

BORDEAUX, JEAN, *How To Talk More Effectively.* Chicago: American Technical Society.

CROUCH, WILLIAM G., and ZETLER, ROBERT L., *Guide to Technical Writing.* New York: Ronald Press.

GAUM, CARL G., GRAVES and HOFFMAN, *Report Writing.* Englewood Cliffs, N.J.: Prentice-Hall.

THOMPSON, WAYNE N., *Fundamentals of Communication.* New York: McGraw-Hill Book Co.

WARRINGER, JOHN E. and GRIFFITH, FRANCIS, *English Grammar and Composition; A Complete Handbook.* New York: Harcourt, Brace & Co.

WITTY, PAUL, *How to Improve Your Reading.* Chicago: Science Research Associates.

YOUNG, CHARLES E., and SYMONIK, EMIL F., *Practical English, Introduction to Composition.* New York: McGraw-Hill Book Co.

COURSE OUTLINES: FIRST YEAR, SECOND SEMESTER

ER 164, Technical Mathematics II (Applied Analytical Geometry and Calculus)

Hours Required

Class, 4; Laboratory, 0

Description

Mathematics used in solving problems involving vector and harmonic motion; complex rotation and vector algebra; functions and graphs; graphic methods used in solving problems relating to slope and rate of slope change; basic calculus, including limits, derivations, and integrations; mechanics of La Place operational calculus as related to the study of control circuits; problem assignments illustrating applications; oscilloscope demonstrations showing mathematical interpretations of electric waveforms; differentiation and integration to provide an understanding of expressions frequently encountered in technical literature. Prerequisite: ER 114 and ER 115.

Note: The correlation of mathematics instruction with technical usages found in the first term is continued here with perhaps even greater effectiveness. ER 185, "Time Varying Circuits," is almost completely mathematical in nature and is arranged to parallel closely the introduction of advanced mathematical concepts in this course.

Major Divisions

		Class hours
I.	Trigonometry	8
II.	Vector Algebra	11
III.	Miscellaneous Mathematics	4
IV.	Graphical Methods of Calculus	4
V.	The Functions	2
VI.	Differentiation	10
VII.	Differentiation of Higher Order	2
VIII.	Integration	10
IX.	Additional Trigonometric Functions in Calculus	3
X.	Logarithmic and Exponential Functions	4
XI.	Hyperbolic Functions	4
XII.	Mathematical Series	3
XIII.	La Place Transforms	3

DIVISION I. Trigonometry—8 hours

A. Identities
B. Trigonometric equations
C. Addition of sine waves (mathematical)
D. Amplitude and phase relationships
E. Harmonically related sine waves
F. Analysis of nonsine waves
G. Lissajous figures

DIVISION II. Vector Algebra—11 hours

A. Complex notation
  1. Addition
  2. Subtraction
  3. Multiplication
  4. Division
B. Polar notations
  1. Addition
  2. Subtraction
  3. Multiplication
  4. Division
C. Changing vector notations
D. Rotation of vectors
E. Eiler's equation
F. Demoinre's theorem

DIVISION III. Miscellaneous Mathematics—4 hours

A. Addition and subtraction tricks
B. Short cuts in multiplication
C. Short cuts in finding square roots
D. Partial fractions
E. Relative errors
F. The graph paper as a calculator

DIVISION IV. Graphical Methods of Calculus—4 hours

A. Slopes and rate of change
B. Increments—work force diagrams
C. Nonlinear equations—slopes
D. The derivative graphically

E. Maxima and minima
F. Inflection points
G. Areas graphically

DIVISION V. The Functions—2 hours
A. Variables and constants
B. Dependent and independent variables
C. Continuous functions
D. Single value
E. Explicit and implicit

DIVISION VI. Differentiation—10 hours
A. Algebraic methods
B. Limits
C. General rules
D. Where $X=f(y)$
E. Where $X=f(y)n$
F. Sum or difference
G. Maximum and minimum values
H. Basic trigonometric functions
I. $Y=e^u$ where $u=f(x)$
J. Repeated differentiation

DIVISION VII. Differentiation of Higher Order—2 hours
A. Second derivative
B. Application to falling bodies

DIVISION VIII. Integration—10 hours
A. Introduction of integration
B. The integration constant
C. The mechanics of indefinite integral
D. Evaluation of the constant of integration
E. Integrals
F. The integral applied to acceleration
G. Area determination with integrations
H. Average values by integration
I. Integration of basic trigonometric functions
J. Volumes by integration

DIVISION IX. Additional Trigonometric Functions in Calculus—3 hours
A. Inverse functions
B. Electrical application of waves to differentiation and integration circuits

DIVISION X. Logarithmic and Exponential Functions—4 hours
A. Exponential function
B. Exponential functions in calculus
C. Natural logarithms
D. Electrical transients

DIVISION XI. Hyperbolic Functions—4 hours
A. The hyperbolic functions
B. Integration and differentiation
C. The hyperbolic function in electrical applications

DIVISION XII. Mathematical Series—3 hours
A. MacLaurin
B. Taylor
C. Fourier
D. Wave analysis by tables and graphs

DIVISION XIII. La Place Transforms—3 hours
A. The mechanics of the La Place tables
B. Electrical application of the La Place

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

COOKE, NELSON M., *Mathematics for Electricians and Radiomen.* New York: McGraw-Hill Book Co.

FISCHER, BERNHARD *and* JACOBS, HERBERT V. *Elements of Mathematics for Radio, TV, and Electronics.* New York: The Macmillan Co.

FREILICK, J. S. *and* others, *Algebra for Problem Solving, Book I and II.* New York: Houghton Mifflin Book Co.

HARRIS, CHARLES O., *Slide Rule Simplified.* Chicago: American Technical Society.

KEASEY, MILES A.; KLINE, GEORGE A. *and* MCILHATTEN, DAVID A., *Engineering Mathematics.* New York: The Blakiston Co.

NODELMAN, H. M. *and* SMITH, F., *Mathematics for Electronics with Applications.* New York: McGraw-Hill Book Co.

RICE, HAROLD S. *and* MCKNIGHT, RAYMOND M., *Technical Mathematics with Calculus.* New York: McGraw-Hill Book Co.

RICHARDSON, M., *Fundamentals of Mathematics.* New York: The Macmillan Co.

RICHMOND, A. E., *Calculus for Electronics.* New York: The Macmillan Co.

SINGER, BERTRAND B., *Basic Mathematics.* New York: McGraw-Hill Book Co.

TUITES, C. E., *Basic Mathematics for Technical Courses.* Englewood Cliffs, N.J.: Prentice-Hall Book Co

ER 185, Time Varying Circuits

Hours Required

Class, 3; Laboratory, 6

Description

Characteristics of alternating current waves and time varying circuits; analyzing the behavior of alternating current components; phase and power factor; power measurement under balanced and unbalanced conditions in delta and wye connected systems; two-phase and three-phase systems; application of vector algebra in the analysis of series and parallel combinations of impedance. Prerequisites: ER 114 and ER 115.

Note: The material in this course must be treated as a mathematics-based science. The mathematical principles required for the analysis and understanding of these circuits is introduced in the concurrent course, ER 164 Technical Mathematics. It will be necessary, however, to assign laboratory time for additional *applied mathematics* instruction in order to provide the depth of understanding that is required in this course.

Major Divisions

	Class hours	*Laboratory hours*
I. Sine Waves	8	9
II. Circuit Fundamentals	9	21
III. Alternating Current Phasors (Vectors)	6	9
IV. Series and Parallel AC Circuits	9	21
V. Polyphase Systems	9	21
VI. Two-phase Systems	9	21
VII. Integrating Circuits	1	3
VIII. Differentiating Circuits	3	6
IX. Miscellaneous Alternating Circuits	3	6

Division I. Sine Waves

A. Units of instruction—8 hours
   1. Generation and equations
      a. Wave shapes
      b. Graphical plots
      c. Equation of sine waves
   2. Space, electrical degrees, poles, and RPM
      a. Relationship space electrical degrees
      b. Relationship poles and RPM
   3. Radians, average and maximum values
      a. Radians and speed
      b. Average and maximum sine waves values
   4. Effective values and effective resistance
      a. Meaning of effective values
      b. Finding RMS values
      c. AC and DC resistances

B. Laboratory projects—9 hours
   1. Wave plotting and graphical addition of waves
   2. Calculations of average, effective values of sine waves

Division II. Circuit Fundamentals

A. Units of instruction—9 hours
   1. Inductors, inductive reactance, and phase angles
      a. Inductor effect
      b. Mathematics
      c. Time angles
   2. Capacitors, capacitive reactance, phase angles, and charging current
      a. Capacitor effect on AC circuits
      b. Mathematics
      c. Time angles
   3. Addition, subtraction, product of sine waves; review
   4. Volt amperes, power factor, reactive power, power, and their importance
      a. Ohm's law for AC circuit
      b. Component resolution of volt amperes
      c. Power factor improvement
      d. Loading of circuits

B. Laboratory projects—21 hours
   1. Effective resistance and DC resistance
   2. Inductances, inductive reactance, and current through inductors
   3. Capacitors, capacitive reactance, and current through capacitors
   4. Selected problems

DIVISION III. Alternating Current Phasors (Vectors)

A. Units of instruction—6 hours
   1. Vector representation. AC quantities and applications of mathematics
   2. Polar and rectangular co-ordinates. AC quantities and application of mathematics
   3. Addition and subtraction of vectors. AC quantities and applications of mathematics
   4. Multiplication, division, and roots of AC vector quantities

B. Laboratory projects—9 hours
   1. Voltamperes, power factor, reactive power measurements
   2. Selected problem

DIVISION IV. Series and Parallel AC Circuits

A. Units of instruction—9 hours
   1. Single-phase systems
      a. Generators working into loads
      b. Effect on KW and KVA of generators
      c. Voltage drop
   2. Series circuits (2 element)
      a. RR circuits
      b. RC circuits
      c. RL circuits
   3. Series circuits (3 element) and resonance
      a. RLC circuits
      b. Voltage, current, and phase angles
      c. Circuit resonance
   4. Parallel circuits (2 elements)
      a. RR circuits
      b. RC circuits
      c. RL circuits
   5. Parallel circuits (3 element) and resonance
      a. RLC circuits
      b. Voltage, current, and phase angle
      c. Resonance
   6. Series parallel circuits (Mesh laws solution)
      a. Circuit simplification
      b. Calculation using vectors
      c. Mesh nets

B. Laboratory projects—21 hours
   1. Plotting and obtaining instantaneous values from scope (use electronic switch)
   2. Selected problems
   3. Series circuits lab (nonresonance)
   4. Parallel circuits lab (nonresonance)
   5. Resonance lab (series and parallel)
   6. Series—parallel circuits

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DIVISION V. Polyphase Systems

A. Units of instruction—9 hours
   1. Polyphase generation and advantages
      a. History
      b. Contrast 1 phase, 2 phase, and 3 phase generators
      c. Distribution of various phases
   2. Power measurement in three-phase circuits
      a. Blondel's theorem
      b. Two- or three-wattmeter methods
      c. Power factor and measurement
   3. Double subscript notation vector representation and phase rotation
      a. Manipulations
      b. Reversing vectors
      c. Phase rotation and P.R. meters
   4. Balanced wye systems (3-wire and 4-wire)
      a. Phase angles
      b. Three-phase power, law, and phase shifts
      c. Uses
      d. Grounds
      e. Harmonics
   5. Unbalanced wye systems (3-wire and 4-wire)—harmonics
   6. Balanced delta systems (3-wire and 4-wire)—harmonics
   7. Unbalanced delta systems (3-wire and 4-wire)—harmonics
   8. Mathematical conversion delta to wye and wye to delta
      a. Formulas
      b. Clearing networks
   9. Systems using combination wye and delta systems
      a. Advantages
      b. Commercial voltages
      c. Zigzag connections

B. Laboratory projects—21 hours
   1. Power measurement in three-phase circuits (3-wire and 4-wire)
   2. Balanced wye and delta circuits (unity and nonunity power factors)
   3. Unbalanced wye and delta circuits (unity and nonunity power factors)
   4. Combination of delta and wye circuits

DIVISION VI. Two-Phase Circuits

A. Units of instruction—1 hour
   1. History, use, and relationship
      a. History
      b. Advantages and disadvantages

c. Obsolete and residual
2. Three-wire Edison and two-phase circuits
a. Advantages of Edison's system
b. Measurement
B. Laboratory projects—3 hours
1. Two-phase measurements and vectors
2. Edison 3-wire system vs 2-wire systems measurements of voltage regulation

DIVISION VII. Integrating Circuits
A. Units of instruction—3 hours
1. Electrical response to sinusoidal waves
a. The integrator
b. Influence of component value
c. Commercial uses
2. Electrical response to nonsinusoidal waves
a. Square wave
b. Pulse wave
c. Influence of component sizes
B. Laboratory projects—6 hours
1. Graphical plot of results to waves (RC and RL)
2. Scope measurement of integrators (RC and RL)

DIVISION VIII: Differentiating Circuits
A. Units of instruction—3 hours
1. Electrical response to sinusoidal waves
a. The differentiator
b. Influence of component value
c. Commercial uses
2. Electrical response to nonsinusoidal waves
a. Square waves
b. Pulse waves
c. Sawtooth waves
d. Influence of component values
B. Laboratory projects—6 hours
1. Graphical plot of response to sinusoidal waves
2. Scope measurement of nonsinusoidal waves

DIVISION IX. Miscellaneous Alternating Circuits
A. Units of instruction—3 hours
1. Methods of wave analysis
a. Scopes and graphical determination
b. Mathematical analysis
2. Electrical transients
a. Source and results
b. Mathematical treatment
3. Effects of harmonics
a. Source
b. Effect
c. Laws of analysis
B. Laboratory projects—6 hours
1. Wave analysis from scope picture and prints
2. Make up laboratory for those who need additional experience for advanced projects

Texts and References

Select one of the books on the following list for a text. Others may be used for references.

ANDRES, P. G., *Basic Mathematics for Engineers.* New York: John Wiley & Sons.

DAWES, CHESTER L., *Electrical Engineering Vol. II.* New York: McGraw-Hill Book Co.

FITCH, SYLVAN *and* POTTER, T. L., *Theory of A. C. Circuits.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

MORECOCK, EARLE M., *Alternating-Current Circuits.* New York: McGraw-Hill Book Co.

VAN VALKENBURG, NOOGER *and* NEVILLE, INC., *Basic Electricity, Volumes 3 & 4. Alternating Current, Resistance, Capacitance in A. C., etc.* New York: John F. Rider Publisher, Inc.

ER 165, Basic Electronics

Hours Required

Class, 3; Laboratory, 6

Description

Introduction to the technical concepts of electronic components and circuits. Principles of vacuum tubes and transistors; tuned circuits and basic circuits for power supplies, detectors, amplifiers, and oscillators; radio receivers; cathode-ray oscilloscopes; use of basic test devices and measuring instruments. It is designed to follow the course Direct Current Circuits and Machines (ER 115) and should be taken concurrently with Time Varying Circuits (ER 185).

Note: The circuit analysis in this course makes use of mathematical forms in the sequence used in ER 164 *Technical Mathematics II.* Incremental changes, for example, are explained by the "delta" notation in the first unit of the course and by calculus concepts in the latter units.

Major Divisions

	Class hours	*Laboratory hours*
I. Introduction to Radio	4	8
II. Vacuum Tube Characteristics	6	12
III. Semiconductor Characteristics	6	12
IV. Power Supplies	5	10
V. Audio Amplifiers	7	14
VI. Tuning Circuits	4	8
VII. Radio-Frequency Amplifiers	4	8
VIII. Detector Circuits	5	10
IX. Receiving Circuits	6	12
X. Test Equipment	4	8

DIVISION I. Introduction to Radio

A. Units of instruction—4 hours
   1. History of radio communication
      a. Early experimenters
      b. Commercial and amateur uses of radio
   2. Various uses of electronics
      a. Industrial controls and instrumentation
      b. Microwaves and radar
      c. Television
      d. Medical applications
   3. Sound wave characteristics
      a. Frequency, amplitude, and waveforms, and the impressions of pitch, loudness, and timbre; beats
      b. Characteristics of the ear; frequency range, loudness response
      c. Speed of sound; directional behavior
      d. Electro-acoustic transducers; microphones, phonograph pickups, speakers, and ultrasonic crystals
   4. Simplified radio transmission and reception system
      a. Radio wave characteristics—comparison of sound waves in air and electromagnetic waves in space
      b. Amplitude modulation and frequency modulation (simple illustrations)
      c. Functions of a receiver—antenna, tuning, detection

B. Laboratory projects—8 hours
   1. Introductory demonstration
      a. Display of "antique" radio apparatus that may be available
      b. Communications receiver demonstration—listening to the signals of various types of foreign, commercial and amateur services using radio communications
      c. Observation of training panels that are connected to form a typical receiver. Examination of electronic components and identification of symbols.
   2. Soldering, splicing, and cabling; practice in making common splices and use of terminals. May include soldering for printed circuits
   3. Construction of crystal receiver. Assembly of a kit, or construction of simple

breadboard set, wired in accordance with the procedures given in the preceding laboratory project, to show essential functions of a receiver that will be studied in detail later

4. Transmitter demonstration, using instructional panels. May be conducted in conjunction with receiver demonstration (1c)
5. Sound and hearing demonstration
   a. Electrical outputs from a microphone and electric waves from a phonograph and from an audio oscillator may be pictured on an oscilloscope at the same time their sound is heard from a loud speaker
   b. Characteristics of the human ear may be shown by variations of frequency and intensity of the signal
   c. Several oscillators may be used to supply complex waveforms and show harmonic relations. The phenomenon of beats will be illustrated visually and audibly

DIVISION II. Vacuum Tubes

A. Units of instruction—6 hours
1. Diodes
   a. Edison effect; electron emission and contact potential
   b. Series and parallel filament connections
   c. Characteristics curves; saturation, rectification and detection
2. Triodes
   a. Action of control grid
   b. Characteristic curves
   c. Amplification factor
   d. Plate resistance; transconductance
   e. Voltage amplification; equivalent circuit
3. Tetrodes and Pentodes
   a. Effect of screen grid
   b. Characteristic curves; negative resistance
   c. Effect of suppressor grid
   d. Beam power tubes
   e. Characteristic curves of pentodes and beam power tubes

B. Laboratory projects—12 hours
1. Tube dissection
   a. Cutting apart piece-by-piece of several discarded tubes (both metal and glass) by each student
   b. Freehand sketching of each element, and of the tube's internal structure
   c. Reference to published tube data for symbol and manufacturer's description of each tube
2. Diode characteristics
   a. Voltage-current relationships taken with equipment connected by student crews and checked by instructor. With a duo-diode, curves may be compared for one section and both sections in parallel.
   b. Informal report with graphs of experimentally obtained data, comparison with published characteristics, and comments on any discrepancies
3. Triode characteristics
   a. Data for transfer curves taken with student-connected apparatus
   b. Informal report, as in preceding experiment
4. Pentode characteristics
   a. Similar procedure as for triode characteristics. Separate sets of data should be taken for sharp cut-off and for remote cut-off types of pentodes
   b. Informal report with data presented on curves that may be compared with those in tube manual
5. Tube characteristics calculations
   a. Calculation of amplification factor, plate resistance, and transconductance, from the curves plotted for triode and pentode tubes
   b. Informal report showing procedures used, and evaluation of units
6. Demonstration of special tubes if time permits, attention may be given to special tubes, such as electron-ray indicators and power tubes for transmitters

DIVISION III. Semiconductor Characteristics

A. Units of instruction—6 hours
1. Semiconductor diode characteristics
   a. Valence electrons
   b. Crystal lattice

c. Donors and acceptors
d. P–N junctions
2. Semiconductor rectifiers
a. Crystal diodes
b. Power rectifiers
3. Transistors
a. Point-contact transistors
b. Junction transistors
c. Transistor parameters
d. Power transistors

B. Laboratory projects—12 hours
1. Semiconductor diode characteristics
a. Measurements for plotting forward and reserve voltage-current relations
b. Informal report
2. Characteristics of junction transistors and surface-barrier transistors
a. Examination of effects of changing operating voltages and currents
b. Informal report
3. Common-base amplifier characteristics
a. Gain and frequency response measurements
b. Biasing methods
c. Informal report
4. Common-emitter amplifier characteristics. Procedure similar to experiment 3, above
5. Bias and stabilization
Measurements in circuits with fixed bias and with self bias
6. Supplement. If time allows, basic transistor receiver circuits may be connected, serving as an introduction to details that will be studied in advanced courses

DIVISION IV. Power Supplies

A. Units of instruction—5 hours
1. Rectifier circuits
a. Half-wave and full-wave rectification
b. Bridge rectifiers
c. Metallic-oxide rectifiers
d. Peak inverse voltage
2. Voltage multipliers; transformerless power supplies
a. Doubler circuits
b. Triplers and quadruplers
3. Filter circuits
a. Choke input; capacitor input; resistance-capacitance filters
b. Voltage dividers; bleeders
4. Other types of power supplies
a. Non-synchronous vibrators
b. Synchronous vibrators
c. Dynamotors
d. Inverter circuits
5. Voltage regulation
a. Ballast tubes
b. Glow-tube regulator
c. Electronic regulation
d. Saturable reactor regulation

B. Laboratory projects—10 hours
1. Transformer familiarization
a. Examination of new or used power transformers—each student should check several units
b. Ohmmeter measurements for lead identification
c. Voltage measurement of windings. Reduced voltage may be applied to the primary as a safety precaution
d. Informal report showing results, with reference to standard transformer color coding
2. Demonstration of typical power supply, with student reports of observations
a. Waveforms at various points
b. Output voltages and ripple with various filters
c. Measurement of regulation with various filters
d. Comparison of full-wave and half-wave rectification
e. Correction of faults in power supplies
f. Informal reports
3. Voltage regulator tubes
a. Connection of voltage regulator tube circuit
b. Collection of data for graphically showing regulator action for conditions for changing line voltage and for changing values of load
c. Compare voltage—current curves of 56–51 and B2
d. Informal report
4. Voltage divider design
a. Problem in figuring resistance and wattage ratings for a divider supplying several loads with different voltages and currents. Check of computations by measurements on the actual circuit
b. Informal report

5. Vibrators and dynamotors
   a. Examination and testing of a vibrator power supply, such as found in car radios
   b. Examination of dynamotor, generator, or motor, to note construction features of rotating machines
   c. Informal report

DIVISION V. Audio Amplifiers

A. Units of instruction—7 hours
   1. Amplifier classification
      a. Classification by use—voltage and power amplifiers
      b. Classification by bias—Class A, Class B, Class AB, and Class C
      c. Classification by frequency response: audio, intermediate, radio, video and broad band
   2. Distortion in amplifiers
      a. Frequency distortion
      b. Phase distortion
      c. Amplitude distortion
   3. Coupling methods
      a. Resistance-capacitance coupling, equivalent circuits
      b. Impedance coupling
      c. Transformer coupling
      d. Direct coupling—balanced amplifier
   4. Feedback amplifiers
      a. Effects of positive and negative feedback
      b. Advantages of negative feedback—reduction of noise and distortion, improvement of frequency response, stability and independence of load change
      c. Negative feedback circuits—current feedback and voltage feedback
   5. Phase inverters
      a. Transformer inverters—phase splitters
      b. Paraphase amplifiers—inverters
   6. Power amplifiers
      a. Ratings—maximum output, efficiency, power sensitivity
      b. Power diagrams; load line
      c. Push-pull amplifiers; graphical analysis
      d. Output transformers; impedance matching

B. Laboratory projects—14 hours
   1. Resistance-capacitance coupled amplifier
      a. Frequency response measurement
      b. Voltage amplification measurement
      c. Effect of load resistance value
      d. Effect of cathode by-passing
      e. Informal report
   2. Impedance coupled amplifier
      a. Gain and frequency response measurement
      b. Informal report
   3. Transformer coupled amplifier
      a. Gain and frequency measurements
      b. Effect of turns-ratio (repeat part (a) with a different transformer)
      c. Audio system testing. Demonstration of noise, distortion, and power measurements
      d. Informal report

DIVISION VI. Tuning Circuits

A. Units of instruction—4 hours
   1. Series resonant circuits
      a. Impedance variation with frequency
      b. Applications in electronics
   2. Parallel resonant circuits
      a. Effect of frequency on voltage, current, and impedance
      b. Uses in tube circuits
   3. Resonance curves
      a. Circuit Q
      b. Half-power points
   4. Selectivity
      a. Design characteristics
      b. Fidelity
      c. L/C ratio

B. Laboratory projects—8 hours
   1. Analysis of capacitive and inductive reactances
   2. Audio-frequency power amplifier
      a. Measurement of output transformer turns ratio and impedance ratio
      b. Measurement of power output
      c. Measurement of power sensitivity
      d. Informal report
   3. Phase-splitter
      a. Check of signal amplitude and phase relations
      b. Changes due to faults
      c. Informal report
   4. Push-pull audio power amplifier
      a. Balance of the circuit
      b. Output impedance matching
      c. Troubleshooting
      d. Informal report

5. Audio systems
   a. Demonstration of institutional systems of intercommunications and sound distribution
   b. Selection and interconnection of components of a high-fidelity system
   c. Experimental measurements showing variations with frequency
   d. Effects of series and parallel combinations
6. Alternating current circuit analysis
   a. Voltage measurements with capacitance, inductance, and resistance connected across the 60-cycle line
   b. Informal report, with vector analysis of voltages measured
7. Series resonance
   a. Measurements of line current variations with frequency. Current from an audio signal generator found with vacuum tube voltmeter by measuring the voltage across a 100-ohm series resistor
   b. Graph of curves for current variations with capacitor only, inductance only, and their series combination
   c. Measurement and plot of response with a different L/C ratio
   d. Effect of series resistance on Q
   e. Informal report
8. Parallel resonance
   a. Measurements to show effect of parallel tuned circuit, with procedure similar to that in experiment 2 above
   b. Informal report

DIVISION VII. Radio-Frequency Amplifiers

A. Units of instruction—4 hours
   1. Voltage amplification of tuned stages
      a. Effect of coil Q
      b. Gain calculations
   2. Band-pass coupling
      a. Critical coupling
      b. Coupled impedance
   3. Multi-stage amplifiers
      a. Overall response
      b. Control of undesired regeneration
B. Laboratory projects—8 hours
   1. Construction of a tuned-radio-frequency receiver. May be on breadboard or chassis. Detector laboratory power supply and separate audio amplifier may be used, so that only the tuner need be constructed.
   2. Adjustment and operation of tuner
   3. Informal report describing adjustments and results

DIVISION VIII. Detector Circuits

A. Units of instruction—5 hours
   1. Diode detection—practical circuits
   2. Plate detection
      a. Operating point
      b. Cathode bias
   3. Grid detection—grid-leak action
   4. Heterodyne detection—beat frequencies
   5. Regenerative detection—control of feedback
   6. Autodyne detection—frequency limitations
   7. Superregeneration
      a. Separately quenched
      b. Self-quenched circuits
   8. Automatic volume control
      a. Supercontrol tubes
      b. Delayed control
B. Laboratory projects—10 hours
   1. Diode detector
      a. Waveforms of detector in training equipment when fed with modulated signal generator
      b. Informal report of detector action with various values of load
   2. Superheterodyne construction

      This project continues through Division IX, and furnishes the receiver to which test equipment procedures are applied in Division X. The receiver may be a kit, or may be a typical superheterodyne assembled with separately obtained parts. Chassis construction should be used. Laboratory power supply units may be utilized, but a self-contained power supply is preferable. Circuit wiring should begin with the power supply and the output stage, working back to the antenna terminals. Students should have a check list for testing their work themselves before the instructor is asked to locate any errors. Demonstrations of typical circuits for a superheterodyne, using laboratory training aids, may be given by the instructor at appropriate stages of student progress.

DIVISION IX. Receiving Circuits

A. Units of instruction—6 hours
  1. Receiver characteristics—sensitivity, selectivity, fidelity, stability, signal-to-noise ratio
  2. Tuned-radio-frequency receivers
  3. Superheterodyne receivers
     a. Frequency conversion—local oscillator, conversion gain
     b. Converter circuits—pentagrid tubes
     c. Intermediate-frequency characteristics—choice of value, image frequency, tuning ratio, spurious responses
     d. Receiver alignment—trimmers and padders, signal generator connections, output indicators

B. Laboratory projects—12 hours
  Continuation of receiver construction described in Division VIII

DIVISION X. Test Equipment

A. Units of instruction—4 hours
  1. Measuring instruments
     a. Multimeters for measuring resistance, voltage, and current
     b. Output meters
     c. Effect of meter loading
     d. Vacuum tube voltmeters
     e. Circuits requiring high-impedance meters
  2. Cathode-ray-oscilloscope
     a. Principle of operation
     b. Interpretation of patterns
     c. Uses in electronic circuit testing
  3. Miscellaneous equipment
     a. Signal generators
     b. Sweep oscillators
     c. Tube testers
     d. Capacitor checkers
     e. Signal tracers

B. Laboratory projects—12 hours
  1. Testing of tubes and components, using test equipment studies. Units with markings removed may be used for practice, and variations from color code markings may be noted
  2. Operation of oscilloscope
     Use of panel controls. Observation of signal waveforms and Lissajous figures
  3. Application of test instruments to adjustment and troubleshooting of superheterodyne project

Texts and References

Select a text from one of the following books. Others may be used as references.

EVERITT, W. L., *ed.*, *Fundamentals of Radio and Electronics.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

SHEINGOLD, ABRAHAM S., *Fundamentals of Radio Communication.* New York: D. Van Nostrand Co., Inc.

SHRADER, R., *Electronic Communication.* New York: McGraw-Hill Book Co.

SLURZBERG, M. *and* OSTERHELD, W., *Essentials of Radio.* New York: McGraw-Hill Book Co.

For transistor study, a supplementary text should be used with one of the above texts, such as the following:

American Radio Relay League, *The Radio Amateur's Handbook* (latest edition); West Hartford, Conn.: American Radio Relay League, Inc.

DE FRANCE, J., *Electron Tubes and Semiconductors.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

EVANS, W. H. *ed.*, *Experiments in Electronics.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

KIVER, M. S., *Transistors in Radio, Television, and Electronics.* New York: McGraw-Hill Book Co.

LANGFORD-SMITH, F., *Radiotron Designer's Handbook.* Harrison, N.J.: Radio Corp. of America.

RIDDLE, R. L. *and* RISTENBATT, M. P., *Transistor Physics and Circuits.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

RIDER, J. F. *and* USLAN, S. D., *Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses.* New York: John F. Rider, Inc.

TURNER, R. P., *Basic Electronic Test Instruments.* New York: Rinehart Books, Inc.

ZBAR, P. B. *and* SCHILDKRAUT, S., *Basic Radio and Radio-Receiver Servicing.* New York: McGraw-Hill Book Co.

G 111, Shop Processes

Hours Required

Class, 1; Laboratory, 2

Description

Course is designed to help the individual student develop information in the use of hand tools, machine tools, equipment, and various types of materials which he will encounter in his work as a technician. Laboratory exercises are designed to introduce students to tools, materials, and equipment with which they are unfamiliar rather than to give students opportunity to develop proficiency only in one area. Shop safety is stressed.

Major Divisions

	Laboratory hours
I. Shop Details	3
II. Shop Organization	3
III. Bench Work	15
IV. Machine Shop Tool, Equipment, and Exercises	18
V. Miscellaneous Materials	9

DIVISION I. Shop Details—3 hours

A. Details from drafting room
   1. Pencil sketches
   2. Blueprints
   3. Other
B. Templates and patterns
   1. Paper
   2. Wood
   3. Metal
   4. Plastic

DIVISION II. Shop Organization—3 hours

A. Work orders
B. Lists
   1. Bill of material
   2. Shipping
   3. Inventory
C. Time study
   1. Cards
   2. Time and motion
   3. Waste and salvage

DIVISION III. Bench Work—15 hours

A. Layout using scale, square, dividers, protractor, and scriber
B. Filing, polishing, and scraping
   1. Types of files, chisels, and scrapers
   2. Use and care
C. Hacksawing
   1. Types of saws
   2. Mounting of blade
   3. Techniques in use
D. Drilling
   1. Hand drills
   2. Small power drills—uses
E. Threading—internal and external
   1. Types of taps
   2. Size of tap to size of drill
   3. Types of threads
      a. Use of dies
      b. Threading pipe and conduit
F. Exercises in the use of
   1. Pliers
   2. Wrenches—open, closed, adjustable
   3. Clamps, vises
   4. Files
   5. Screwdrivers, punches, pry bars, etc.
   6. Micrometer, vernier, gauge, protractor, trammel, scale, and rule
   7. Hacksaws
   8. Other

DIVISION IV. Machine Shop Tool, Equipment, and Exercises—18 hours

A. Lathe
   1. Exercises in centering, facing, adjusting centers, etc.
   2. Turning and facing work held on mandrels; arbors
   3. Measuring with micrometers
   4. Taper turning and boring

B. Drill press
  1. Rough drilling
  2. Types of drills
  3. Cutting speed and feeding
C. Milling machine
  1. Selection of cutters
  2. Direction of feed
  3. Squaring
D. Forming and shaping metal and plastic
  1. Sheet metal
    a. Types of sheet metals and their uses
    b. Exercises in design, layout and construction of geometric forms used in instrument chassis, raceways, and junction boxes such as:
      (1) Square
      (2) Octagon
      (3) Hexagon
      (4) Pentagon
      (5) Ellipse
    c. Exercises in the use of sheet metal tools and materials such as:
      (1) Shears
      (2) Folding, forming and shaping equipment and machines
      (3) Bench machines and stakes
      (4) Groover, rivet sets, knock-out sets, spot welder, nibbler, gas and electric soldering equipment, metal screws, etc.
  2. Plastics
    a. Types of plastics and uses
    b. Forming, shaping, and drilling
    c. Casting and molding
    d. Fasteners
      (1) Special rivets, screws, and bolts
      (2) Joining plastics to plastics; plastic to metal
  3. Heavy-gauge metals
    a. Hand forging and heat treating
    b. Presses, hydraulic and hand
    c. Casting
    d. Shaper and planer
    e. Welding, gas and electric
  4. Metal fasteners
    a. Types of rivets and uses
    b. Types of bolts, nuts and screws and uses
    c. Types of holders, wire, pipe
      (1) Insulated staples
      (2) Insulated and noninsulated wire and pipe straps
      (3) Plastic, wood and fiber clamps and separators
      (4) Other

DIVISION V. Miscellaneous Materials—9 hours
A. Wire
  1. Wire sizes, types, and uses
    a. Types of connectors
    b. Soldering and splicing
    c. Junction boxes
    d. Raceways and panels
B. Conduit
  1. Thinwall
    a. Threadless connectors
    b. Use of hickey, other benders
    c. Cutting
  2. Rigid
    a. Types of connections and fittings
    b. Cutting, threading, reaming and bending
    c. Uses
C. Insulating materials
D. Wood, wood fiber, hard rubber, and masonite

Students should complete one or two projects applying as many of the machines, tools, and processes as time will permit

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

AUSTIN, JOHN B., *Electric Arc Welding.* Chicago: American Technical Society.

BARICH, DEWEY F. *and* SMITH, L. C., *Metal Work for Industrial Arts Shops.* Chicago: American Technical Society.

BRUCE, LEROY FOWLER, *Sheet Metal Shop Practice.* Chicago: American Technical Society.

CARROLL, JOHN M., *Mechanical Design for Electronics Production.* New York: McGraw-Hill Book Co.

DUBOIS, J. H. *and* PRIBBLE, W. I., *Plastics, Mold Engineering.* Chicago: American Technical Society.

FRANKEL, JACOB PORTER, *Principles of the Properties of Materials.* New York: McGraw-Hill Book Co.

FEIRER, JOHN L., *General Metals.* (second edition) New York: McGraw-Hill Book Co.

GRONEMAN, CHRIS H., *Plastics Made Practical.* Chicago: Bruce Publishing Co.

KNOBLAUGH, RALPH R., *Modelmaking for Industrial Design*. New York: McGraw-Hill Book Co.

MERSEREAU, SAMUEL FOSTER, Revised by Reen, Calvin G. *and* Holderman, Kenneth L., *Materials of Industry*. Fourth Ed., New York: McGraw-Hill Book Co.

PORTER, MORGAN H., *Oxyacetylene Welding*. Chicago: American Technical Society.

STRASSER, FREDERICO, *Practical Design of Sheet Metal Stampings*. Philadelphia: Chilton Publishing Co.

TURNER, WILLIAM P. *and* OWEN, HALSEY F., *Machine-Tool Work*. Purdue University, second edition.

VAN DOREN, HAROLD, *A Practical Guide to Product Design and Development*. New York: McGraw-Hill Book Co.

G 161, Technical Report Writing

Hours Required

Class, 1; Laboratory, 0

Description

Techniques of collecting and presenting scientific data. Informal reports and formal reports; special types of technical papers. Forms and procedures for technical reports are studied and a pattern is established for all formal reports to be submitted in this and other courses. Prerequisite: G 133 Communication Skills.

Major Divisions

		Class hours
I.	The Scientific Method	4
II.	Techniques of Exposition	6
III.	The Report Form	7

DIVISION I. The Scientific Method—4 hours

1. Meaning of the method
   a. Cumulative nature
   b. Complexity of investigation
2. Characteristics of the scientific method
   a. Reliance on observation
   b. The experimental process
   c. Objectivity
3. Essentials of scientific style
   a. Clarity and precision
   b. Conciseness and directness
4. The problem concept
   a. Types of problems
   b. Setting up a problem

DIVISION II. The Techniques of Exposition—6 hours

1. Definitions
   a. The formal definition
   b. The operational definition
   c. The informal definition
2. The expository paragraph
   a. Length
   b. Structure
3. Progression. Maintaining unity, coherence, and emphasis
4. Elements of style
   a. Sentence structure
      (1) Relation of ideas
      (2) Faulty references: pronouns and modifiers
      (3) Balance and parallelism
      (4) Revision
   b. Style problems
      (1) Shoptalk and jargon
      (2) Achieving readability
5. Analysis of examples

DIVISION III. The Report Form—7 hours

1. Characteristics of the report
2. Report functions
3. Informal reports
   a. Short-form reports
      (1) Memorandum reports
      (2) Business letter reports
      (3) Outline reports
4. The formal report
   a. Arrangement
      (1) Cover and title pages
      (2) Table of contents
      (3) Summary of abstracts
      (4) Body of the report
      (5) Bibliography and appendix
      (6) Graphs and drawings
   b. Preparation
      (1) Collecting, selecting, and arranging material
      (2) Writing and revising the report
5. Special types of papers
   a. The abstract
   b. Process explanations
   c. The case history
   d. The book review

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BLICKLE, M. D. and HOUP, K. W., *Reports for Science and Industry.* New York: Henry Holt & Co.

CROUCH, WILLIAM G. *and* ZETLER, ROBERT L., *A Guide to Technical Writing*. New York: Ronald Press.

GAUM, CARL G., GRAVES, HAROLD F., and HOFFMAN, LYNE S. S., *Report Writing*. Englewood Cliffs, N.J.: Prentice-Hall.

GUNNING, ROBERT, *The Technique of Clear Writing*. New York: McGraw-Hill Book Co.

HICKS, T. G., *Successful Technical Writing*. New York: McGraw-Hill Book Co.

PHILCO TECHNOLOGICAL CENTER, *Technical Writing Guide*, Philadelphia 32, Pa.: The Center, Department 259.

RHODES, FRED, *and* JOHNSON, HERBERT F., *Technical Report Writing*. New York: McGraw-Hill Book Co.

SANTMYERS, SELBY S., *Practical Report Writing*. Scranton, Pa.: International Textbook Co.

SOUTHER, JAMES W., *Technical Report Writing*. New York: John Wiley & Sons, Inc.

ULMAN, JOSEPH N., Jr., *and* GOULD, J. R., *Technical Reporting*. New York: Henry Holt & Co.

G 162, Graphic Analysis

Hours Required

Class, 1; Laboratory, 3

Description

Graphic representation and graphic analysis. Layout methods used in pattern and template work. Graphs, charts, and plots with an introduction to descriptive geometry and graphic calculus.

Major Divisions

	Class hours	*Laboratory hours*
I. Symbol Drawings	2	6
II. Sheet Metal Layouts	1	3
III. Drawings for Machine Reproduction	1	3
IV. Graph Plotting	2	6
V. Field Survey Work	2	9
VI. Charts	2	6
VII. Nomographs	2	6
VIII. Basic Descriptive Geometry	2	6
IX. Graphic Calculus	3	6

Division I. Symbol Drawings

A. Units of instruction—2 hours
   1. Electrical symbols (instruments and templates)
   2. Electronic symbols (instruments and templates)
   3. Control wiring symbols (instruments and templates)

B. Laboratory projects—6 hours
   1. Trace and diagram the circuit of a piece of electronic equipment using templates
   2. Trace and diagram the circuit of a piece of electrical equipment using drawing instruments
   3. Reproduce a complex control diagram

Division II. Sheet Metal Layouts

A. Units of instruction—1 hour
   1. Layout methods
      a. Layout tools
      b. Reference points
      c. Arcs and curves
      d. Holes
   2. Cutting methods
      a. Snips and shears
      b. Machines
      c. Hole cutters
   3. Bending methods
      a. Bending in vise
      b. Metal folders
   4. Bending allowances
      a. Allowable radius
      b. How to bend radius
   5. Fasteners and fastening methods
      a. Metal screws
      b. Spot welding
      c. Torch fastening
      d. Soldering

B. Laboratory projects—3 hours
   Prepare full scale drawings showing all cuts and bends for a complete chassis or subchassis

Division III. Drawings for Machine Reproduction

A. Units of instruction—1 hour
   1. Reproduction methods and machines
      a. Blueprint
      b. Sepia
      c. Mimeograph
      d. Ditto
      e. Multilith
      f. Ozalid printer
   2. Duplicating masters
      a. Care of masters
      b. Type masters
      c. Storing masters
      d. Corrections and changes of masters

B. Laboratory projects—3 hours
   Prepare a simple machine drawing for

reproduction and reproduce as blueprints, sepia, ditto, and multilith

Division IV. Graph Plotting

A. Units of instruction—2 hours
1. Types of graph paper
a. Rectangular
(1) Inch scale
(2) Centimeter scale
b. Semi-log
c. Log-log
d. Circular
2. Proper scaling of paper
a. Selection of scales
b. Broken scales
c. Double scales
3. Points and lines
a. Point plotting
b. Line identification
c. Name plate
4. Data from graphs
a. Proper data from graph and calculations
b. Error points

B. Laboratory projects—6 hours
Plot and obtain information from the following type graphs:
1. Rectangular
2. Polar
3. Semi-log
4. Log-log
5. Tri-linear

Division V. Field Survey Work (with Applications to Radiation Patterns)

A. Units of Instruction—2 hours
1. Radiation field strength surveys
a. Measurements
b. Plotting
2. Contour maps
a. Elevation maps
b. Relative antenna height
c. Symbols

B. Laboratory projects—6 hours
From information furnished, plot a radiation pattern of a particular antenna arrangement.

Division VI. Charts

A. Units of instruction—2 hours
Purpose and method of presenting data
1. Bar graph
2. Area graph
3. Picture chart
4. Volume chart
5. Flow chart
6. Pie charts

B. Laboratory projects—6 hours
From information furnished, the student prepares one chart for each of the above and two charts of own selection

Division VII. Nomographs

A. Units of instruction—2 hours
1. Nomographic use of charts
a. Chart use and purpose
b. Interpolation from chart
2. Selection of scales for charts
a. Use of formula
b. Parallel or Z chart
c. Limits
d. Scaling
3. Methods of plotting charts
a. Making divisions
b. Selecting spacing
c. The dependent variable

B. Laboratory projects—6 hours
1. Construction of alignment parallel chart
2. Construction of Z alignment chart

Division VIII. Basic Descriptive Geometry

A. Units of instruction—2 hours
1. Analysis of views in quadrants
a. The four quadrants
b. Folded box views
2. Projections in planes
a. Point
(1) Locating points in quadrants
(2) Distance between points
b. Line
(1) Measurement of lines with two views given
(2) Two lines in different planes
(3) Intersecting lines
c. Plane
(1) Locating plane from three points
(2) Find angle of intersection
d. Intersection of planes
(1) Intersecting planes and missing views
(2) Applied problems

B. Laboratory projects—6 hours
1. Basic descriptive geometry problems
2. Problem in applied geometry

DIVISION IX. Graphic Calculus

A. Units of instruction—3 hours

1. Graphic integration
   a. Increments by blocks
   b. Ray method of integration
   c. Plotting the integral
2. Graphic differentiation
   a. Graphic methods
   b. Applied problems

B. Laboratory projects—6 hours

Preparation of graphs showing differentiation and integration of various curves

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BISHOP, COLVIN C., *Electric Drafting and Design*. New York: McGraw-Hill Book Co.

FRENCH, T. E. & VIERCK, C. J., *Graphic Science*. New York: McGraw-Hill Book Co.

GIESECKE, FREDERICK E., MITCHELL, ALVA, *and* others, *Technical Drawing*. New York: The Macmillan Co.

KOCHER, STANLEY E., *Electrical Drafting*. Scranton, Pa.: International Textbook Co.

LUZADDER, WARREN J., *Graphics for Engineers*. Englewood Cliffs, N.J.: Prentice-Hall Book Co.

LUZADDER, WARREN J., *Fundamentals of Engineering Drawing*. Englewood Cliffs, N.J.: Prentice-Hall Book Co.

COURSE OUTLINES: SECOND YEAR, THIRD SEMESTER

G 204, Engineering Science

Hours Required

Class, 3; Laboratory, 3

Description

Graphical and mathematical analysis of forces; laws of motion, machines, mechanical power, strength of material, fluid mechanics, and thermal conductivity; basic principles of physics. Principles directly related to the technician field of specialization will be covered in greater detail in subsequent specialized courses. Course work is extremely practical in nature with the emphasis on applied problems.

Major Divisions

	Class hours	*Laboratory hours*
I. Forces	21	21
II. Motion	6	6
III. Work and Power	6	6
IV. Simple Machines	3	3
V. Strength of Materials	3	3
VI. Fluids	3	3
VII. Gases	3	3
VIII. Heat Elements	3	3
IX. Light and Lenses	3	3

DIVISION I. Forces

A. Basic forces—6 hours
   1. Definitions
      a. Definitions
      b. Units of measurement
      c. Metric units
      d. Limits and safety factors
   2. Action and reaction
      a. Laws
      b. Application of laws
      c. Resultants
      d. Vectors
   3. Measurement
      a. Scales
      b. Torsion members
      c. Destruction machines
   4. Tension, compression, and shear
      a. Forces on members
      b. Limits of materials
      c. Elastic limits
   5. Center of gravity
      a. Locating centers
      b. Forces on
B. Laboratory projects—6 hours
   1. Metric system of measurement
   2. Center of gravity (experimental)
C. Resolution and composition of forces—4 hours
   1. Parallelogram of forces
      a. Graphical solution
      b. Mathematical
      c. Force resolution
   2. Two or more forces
      a. Two concurrent forces
      b. Couples
      c. Multi-force
   3. Rectangular components
      a. Force resolution
      b. Resultant
   4. Polygon of forces
      a. Resultant
      b. Equilibrant
      c. Unknown force
D. Laboratory projects—6 hours
   Forces and force resolution
E. Concurrent forces—3 hours
   1. Computation
      a. Parallel forces on members
      b. Nonparallel forces
      c. Distributed loads
   2. Equilibrium
      a. Conditions of equilibrium
      b. Computing

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3. Resolution along axis
   a. Method of solution
   b. Results

F. Laboratory projects—3 hours
   Polygon of forces

G. Parallel forces—3 hours
1. Moments
   a. Law of moments
   b. Application to forces
   c. Application to rotation
2. Levers
   a. Three types of levers
   b. Application to forces
3. Couple
   a. Definition
   b. Effect on rotation
   c. Practical problems

H. Laboratory projects—3 hours
   Levers

I. Nonconcurrent forces—2 hours
1. Conditions of equilibrium
   a. Laws
   b. Forces
2. Solution of typical force systems
   a. Graphical
   b. Mathematical
   c. Safety factors

J. Trusses and structures—3 hours
1. Shear legs
   a. Forces in legs
   b. Free-body diagrams
   c. Calculations of forces
2. Cranes and derricks
   a. Typical units
   b. Loads
   c. Stresses
3. Bridge and roof trusses
   a. Typical units
   b. Types of static loads
   c. Solutions of forces
4. Graphic solutions of various trusses and structures

K. Laboratory projects—3 hours
1. Forces in boom cranes
2. Forces in structures

DIVISION II. Motion

A. Units of instruction—6 hours
1. Linear motion
   a. Speed, distance, acceleration
   b. Free falling body
   c. Projected bodies
2. Angular motion
   a. Gears
   b. Pulleys
   c. Belts
   d. Harmonic motion
   e. Pendulum
   f. Cam and linkage motion

B. Laboratory projects—6 hours
1. Projected body
2. Pendulum
3. Pulleys
4. Gears
5. Simple cams

DIVISION III. Work and Power

A. Units of instruction—6 hours
1. Units of work
   a. Definitions
   b. Formulas for problems
   c. Friction of bodies
2. Work diagrams
3. Power and measurements
   a. Measurement foot pounds per minute
   b. Contrast to work
   c. Prony brake measurement
   d. Efficiency
4. Dynamometers
   a. The machine
   b. Formulas for use

B. Laboratory projects—6 hours
   Measurement of horsepower of motor

DIVISION IV. Simple Machines

A. Units of instruction—3 hours
1. Inclined plane
   a. As a machine
   b. Mechanical advantage
   c. Work done and work loss
2. Winch
   a. The machine
   b. Mechanical advantage
   c. Commercial use
3. Belt and gear drives
   a. Belt speeds
   b. Pulley speeds and direction of rotation
   c. Gear trains, mechanical advantage, rotational direction and differential gears
   d. Worm and worm wheel
4. Pulleys, block, and tackle
5. Differential pulley
   a. Mechanical advantage
   b. Use

6. Screws
   a. Mechanical advantage
   b. Use
   c. Friction

B. Laboratory project—3 hours
Inclined plane—levers and linkage

DIVISION V. Strength of Materials

A. Units of instruction—3 hours
1. Stress deformation, and elastic units
   a. Ultimate strength
   b. Yield points
   c. Deformation of materials
   d. Elasticity
2. Shear and ultimate strength
   a. Unit shear
   b. Applications
   c. Failure of members
3. Factor of safety
   a. Reasons for
   b. Typical factors
4. Torsion of shaft transmitting power
   a. Displacement angle
   b. Shear action
   c. Failures
5. Creep and fatigue

B. Laboratory projects—3 hours
Stress deformation, and strength of materials

DIVISION VI. Fluids

A. Units of instruction—3 hours
1. Liquids, density, specific gravity
   a. Definition
   b. Temperature effects
   c. Measurements
2. Pressure, transmission of pressure
   a. Factors affecting
   b. Gauge and absolute
   c. Transmission and vessel pressure
3. Archimedes' principle and hydrometers
   a. Archimedes' principle
   b. Application to industrial use, i.e. boats, and floats
   c. Hydrometric measurement methods
4. Flow in pipes, friction loss of head
   a. Bernoulli's principle
   b. Analogy to electric systems
   c. Pipe friction, including heads
   d. Discharge rates orifices, flow measurements

B. Laboratory projects—3 hours
Archimedes' principle and hydrometers

DIVISION VII. Gases

A. Units of instruction—3 hours
1. Pressure of gases
   a. Measurement methods
   b. Flow of gases—Bernoulli's principle
   c. Pressure differential and gas flow
2. Gas laws and applications
3. Flow of air
   a. Compressors
   b. Cleaning and water traps
   c. Measuring

B. Laboratory projects—3 hours
Gas laws

DIVISION VIII. Heat Elements

A. Units of instruction—3 hours
1. Heat units
   a. B.T.U.
   b. Measuring B.T.U. of fuels
   c. Purchasing by B.T.U.: fuels, rates, and costs
2. Expansion and contraction due to heat
   a. Expansion coefficient
   b. Bimetals
   c. Expansion joints
3. Specific heat and temperatures of mixtures
   a. Specific heat of matter
   b. Heat of mixtures
   c. Heat loss
4. Heat transfer
   a. Transfer through materials
   b. Application to heat loss and air conditioning
   c. Use of heat transfer constants
   d. Convection, conduction, and radiation
   e. Diffusivity

B. Laboratory projects—3 hours
Specific heat and heat of mixture; transfer heat

DIVISION IX. Light and Lenses

A. Units of instruction—3 hours
1. Nature of light
   a. Light definitions and generation
   b. The spectrum (ultra violet – infra reds)
   c. The eye
2. Transmission of light
   a. Transmission, reflection, and aborption
   b. Velocity, frequency, and wave length
   c. Measuring

3. Lens
    a. Convex lens
    b. Concave lens
    c. Reflectors
    d. Prisms

B. Laboratory projects—1 hour
1. Light
2. Lens
3. Focal centers
4. Spectrum

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BEER, FERDINAND P. and JOHNSTON, RUSSELL E., *Mechanics for Engineers*. New York: McGraw-Hill Book Co.

BLACK, NEWTON HENRY, and LITTLE, ELBERT P., *Introductory Course in College Physics*. New York: The Macmillan Co.

BRENEMAN, JOHN W., *Mechanics*. New York: McGraw-Hill Book Co.

DULL, CHARLES E., METCALFE, H. CLARK, and BROOKS, WILLIAM O., *Modern Physics*, New York: Henry Holt & Co.

HARRIS, N. C., and HEMMERLING, E. N., *Introductory Applied Physics*. New York: McGraw-Hill Book Co.

MERAIN, J. L., *Mechanics Statics, Part I*. New York: John Wiley & Sons.

OLIVO, C. THOMAS, and WAYNE, ALAN, *Basic Science, Part I, Physics*. Albany, N.Y.: Delmarr Publishing Co.

WEBER, R. L., WHITE, MILO, and MANNING, K. V., *Physics for Science and Engineering*. New York: McGraw-Hill Book Co.

WHITE, MARSH WILLIAM, MANNING, K. V., and WEBER, R. L., *Practical Physics*. New York: McGraw-Hill Book Co.

E 213, Electrical Instruments and Measurements

Hours Required

Class, 2; Laboratory, 3

Description

The mechanics and the science of electrical measurements are given thorough treatment in the course. Starting with basic indicating instruments and continuing through complex integrating devices, both the operating principles and the "hardware" are studied. Range extending devices, rectifiers, bridges, and transformers are used in the laboratory to construct metering systems for typical job requirements. Operation, repair and calibration of measuring instruments. Mathematical analysis is used throughout the course with extensive use of vector algebra and trigonometry. Prerequisite: ER 185.

Major Divisions

	Class hours	*Laboratory hours*
I. D.C. Meters	4	6
II. A.C. Indicating Meters	4	3
III. Miscellaneous Indicating Meters	2	3
IV. Integrating Meters	3	12
V. Instrument Transformer	4	6
VI. Special Metering	4	6
VII. Laboratory Measurements	9	9
VIII. Commercial Kilowatt Hour Meters	4	6

Division I. D.C. Meters

A. Units of instruction—4 hours
  1. Galvanometers
    a. Theory
    c. Formula
    c. Construction details
  2. d'Arsonval movements
    a. Straight coils
    b. Concentric coils
    c. Half coils (300° meters)
  3. Shunts and multipliers
    a. Calculations
    b. Temperatures and metals
    c. Leads of multipliers
  4. Thermal meters
    a. Hot wire type
    b. Junction type
    c. Thermal converters
  5. Ohmmeters and meggers
    a. Series ohmmeters
    b. Shunt ohmmeter
    c. Megger
    d. Meggohmer

B. Laboratory projects—6 hours
  Galvanometer movement—Shunts and Multipliers

Division II. A.C. Indicating Meters

A. Units of instruction—4 hours
  1. Rectifier meters
    a. Rectifier principle and types
    b. Linear scale meters
  2. Iron vane
    a. Inclined coil
    b. Weston
    c. Uses and limitations
  3. Dynamometer
    a. Volt meters
    b. Watt meters (1-phase and 3-phase)
    c. Graphic meters

B. Laboratory projects—3 hours
  1. Construction—Sketches and explanations
  2. Calibration of meters
  3. Rescaling of meters

Division III. Miscellaneous Indicating Meters

A. Units of instruction—2 hours
  1. Frequency meters
    a. Frahm Reed
    b. Resonance circuit
    c. Resonance

2. Power factor meters
   a. Tuma, one-phase
   b. Three-phase tuma
3. Synochronoscope—GE iron vane
4. Phase sequence meters
   a. Rotating vane
   b. Light type
5. Meter phase switching
   a. Voltmeter switching
   b. Ammeter switching

B. Laboratory projects—3 hours
1. Meter sketching
2. Meter switching

DIVISION IV. Integrating Meters

A. Units of instruction—3 hours
1. KWH parts and metering terms
   a. Metering definitions
   b. Meter constants and multipliers
   c. Indentification of KWH parts
2. Principles of operation
   a. Rotating field
   b. Disc speeds
   c. Coil variations
3. Multiple element meters
   a. Wye
   b. Delta
   c. Transformer type
4. Meter cleaning, inspection, and mechanical parts
   a. Type cleaner
   b. Inspection methods
   c. Adjustments
5. Three methods of calibration
   a. Portable standard, reference
   b. Counting circuits
   c. Stroboscopic method
6. KVA metering
   a. Circuit using KWH
   b. Westinghouse KVA meter
7. Reactive metering
   a. Purpose
   b. Circuit using KWH

B. Laboratory projects—12 hours
1. Sketching meter components
2. Checking meter constants
3. Meter calibration
4. Meter connection of KVAR and KVA

DIVISION V. Instrument Transformer Metering

A. Units of instruction—4 hours
1. The potential instrument transformer
   a. Types
   b. Ratings
   c. Errors
   d. Compensations
2. The current instrument transformer
   a. Proper meter multipliers due to transformer
   b. Compensation for transformer errors
   c. Types
   d. Ratings
   e. Errors
   f. Compensation
3. The circuits
   a. Potential to board
   b. Current to board
4. The metering constants
   a. Proper meter multiplier due to transformer
   b. Compensation for transformer errors

B. Laboratory projects—6 hours
1. Make a transformer metering connection
2. Visit meter laboratory

DIVISION VI. Special Metering

A. Units of instruction—4 hours
1. Thermal metering
   a. Volt
   b. Amperes
   c. Kilowatt
2. Demand metering
   a. Types and application
   b. Constants
3. Time controlled metering
4. Totalizing meters
5. Carrier current

B. Laboratory projects—6 hours
1. Circuit connection and constants of thermal demands
2. Construction of a small carrier current controlled device

DIVISION VII. Laboratory Measurements

A. Units of instruction—9 hours
1. Loop test
   a. Murray Loop
   b. Varley Loop
2. Bridge measurements
   a. A.C.
      (1) Impedance
      (2) Capacitance
   b. D.C.
      (1) Slide wire
      (2) Dial bridge
      (3) Double bridge

3. Oscillographs (not scopes)
   a. Visual (rotating mirror)
   b. Photographic
   c. Direct recording
4. Potentiometers (including micro-max)
   a. Voltage divides
   b. Standardization
   c. Recording
5. Instrument transformer tests for errors
   a. Potential transformers
   b. Current

B. Laboratory projects—9 hours
1. Loop tests for troubled lines
2. Bridge tests
3. Use of oscillograph

DIVISION VIII. Commercial Kilowatt Hour Meters

A. Units of instruction—4 hours
1. Duncan
2. General Electric
3. Sangamo
4. Westinghouse

B. Laboratory projects—6 hours
Comparison and study of the design and construction of various commercial meters

Texts and References

Select one of the following books for a text. Others may be used as possible references.

EDISON ELECTRIC INSTITUTE, *Electrical Metermans Handbook*. New York: Edison Electric Institute.

DUNN, C. H., *and* BARKER, H. J., *Electric Measurements Manual*. Englewood Cliffs, N. J.: Prentice-Hall Book Co.

HARRIS, F. K., *Electrical Measurements*. New York: John Wiley & Sons, Inc.

LAWS, FRANK A. *Electrical Measurements*. New York: McGraw-Hill Book Co.

MACGAHAN, PAUL, *Electrical Measuring Instruments*. Scranton, Pa.: International Textbook Co.

RHODES, T. J., *Industrial Instruments for Measurement and Control*. New York: McGraw-Hill Book Co.

SMITH, A. W. *and* WEIDENBECK, M. L., *Electric Measurements*. New York: McGraw-Hill Book Co.

STOUT, MELVILLE B., *Basic Electrical Measurements*. Englewood Cliffs, N. J.: Prentice-Hall Book Co.

E 215, Alternating Current Machines

Hours Required

Class, 3; Laboratory, 6

Description

The work in this course is confined to a study of mechanical-electrical power devices. Alternators, single-phase motors and three-phase motors, transformers, voltage regulators, generators, as well as the auxiliary control equipment necessary for these devices are studied. Laboratory work consists mainly of running load tests on selected equipment and studying the characteristic behavior of these units under varying operating conditions. Installation and maintenance requirements for alternating current power equipment are given some attention. Prerequisite: ER 185.

Major Divisions

	Class hours	Laboratory hours
I. Polyphase Systems Review	4	9
II. Transformers (Physical)	3	3
III. Transformer Operational Characteristics	9	16
IV. Three-Phase Transformers	2	8
V. Special Transformers	7	6
VI. Alternators	12	12
VII. Three-Phase Motors	7	15
VIII. Three-Phase Synchronous	2	3
IX. Synchronous Converters	1	3
X. Single-Phase Motors	3	15
XI. Minute Motors	1	12

Division I. Polyphase Systems Review

A. Units of instruction—4 hours
  1. Three-phase generators
    a. Advantages
    b. Mechanical coil placement
    c. Phase angles
  2. Wye connected circuits
    a. Advantages and disadvantages
    b. Volts, amps, power, and phase angles
    c. Open wye
  3. Delta connected circuits
    a. Advantages and disadvantages
    b. Volts, amps, power, and phase angles
    c. Open delta
  4. Three-phase power measurements
    a. Blondel's theorem
    b. 3-, 4-, 2-wire circuits
    c. Circuits for measurement
  5. Two-phase systems
    a. 3-, 4-, and 5-wire system
    b. Reasons for being obsolete

B. Laboratory projects—9 hours
  1. Safety and artifical respiration
  2. Wye and delta loads
  3. Problem laboratory
  4. Unbalanced loads

Division II. Transformers (Physical)

A. Units of instruction—3 hours
  1. Physical construction
    a. Shell type
    b. Core type
    c. Wound type
    d. Coil arrangements
    e. Insulation
    f. Bushings
  2. Cooling of transformers, breathing of transformers
    a. Method
      (1) oil
      (2) air
      (3) fan
      (4) circulating water
      (5) oil-heat interchanger
    b. Reservoir type
  3. Heating and loading
    a. Protecting methods
    b. Load limits
    c. Automatic fans
    d. C.S.P.

4. Installation
   a. Pole
   b. Platform
   c. Ground
   d. Underground

B. Laboratory projects—3 hours
   Transformer inspection

DIVISION III. Transformer Operational Characteristics

A. Units of instruction—9 hours
   1. Turn ratio, voltage ratio, current ratio
      a. Definition of n
      b. $n=\frac{V_1}{V_2}=\frac{I_2}{I_1}$
   2. Transformer vectors under a load, voltage regulation, and efficiency.
      a. Vector construction
      b. Interpreting results of vectors
   3. Transformer testing
      a. Percent regulation
      b. Efficiency
      c. Heat rise
      d. Equivalent circuit

B. Laboratory projects—16 hours
   1. Transformer ratio checks
   2. Heat rise of transformers
   3. Transformer regulation by equivalent circuit

DIVISION IV. Three-Phase Transformers

A. Units of instruction—2 hours
   1. Construction and use of three-phase transformer
      a. Mechanical layout
      b. Advantages
   2. Three-phase banking of transformers
      a. Wye
      b. Delta
      c. Auto
      d. Wye-delta
      e. Delta-wye
      f. Open connections
   3. Grounding practices, lightning protection
      a. Overhead static and arrestors
      b. C.S.P. Transformers
      c. Grounding

B. Laboratory projects—8 hours
   1. Transformer polarity
   2. Three-phase connections

DIVISION V. Special Transformers

A. Units of instruction—7 hours
   1. Auto transformers
      a. Use and dangers
      b. Vector and efficiency
      c. KVA costs
   2. Tap changing transformers
      a. Automatic
      b. Manual
   3. Constant current transformers
      a. Arc circuits
      b. Mechanical construction
      c. Electrical characteristic and dangers
   4. Instrument transformers
      a. Ratios
      b. Loading
      c. Types of current transformers
      d. Types of voltage transformers
   5. Induction voltage regulators
      a. Theory of operation
      b. Uses and installation
      c. 1-phase and 3-phase

B. Laboratory projects—6 hours
   1. Auto transformer tests
   2. Induction regulator construction and performance

DIVISION VI. Alternators

A. Units of instruction—12 hours
   1. Construction, rating, and cooling
      a. Solvent and nonsolvent
      b. KW and KVA
      c. Air and hydrogen
   2. Generation wave shapes, and coil connections
      a. Non-sinusoidal waves
      b. Short pitch and distributed windings
      c. Coil connections
   3. Armature reaction
      a. Current in phase
      b. Lagging currents
      c. Leading currents
      d. Effect of above
   4. Voltage regulation and generator constants
      a. Vector diagram
      b. Synchronous reactance
      c. Regulation and efficiency

5. Generator paralleling and parallel operations
   a. Three methods of synchronizing
   b. Effect of excitation on parallel operation
   c. Effect of engine governor on parallel operation

B. Laboratory projects—12 hours
1. Generator wave shape and coil connections
2. Generator constants
3. Paralleling and parallel operation induction

DIVISION VII. Three-Phase Motors

A. Units of instruction
1. Motor principle (rotating field)
   a. Slip, rotor frequency, and rotor currents
   b. Vector theory of rotation
   c. Tin can motors
2. Induction motor construction—stator slots
   a. Skew of slots
   b. Slot shape and effect
   c. Bearings
   d. Stator windings
3. Rotor currents, rotor torque, and rotor frequency
4. The squirrel cage motor principles and characteristics
   a. Construction
   b. Classes
   c. Curves
   d. Applications
5. Starting induction motors
   a. Across line
   b. Auto-transformers
   c. Resistors
6. Double squirrel cage motors and characteristics
   a. Mechanical details
   b. Resistance variation
   c. Starting currents
7. Wound rotor motors and characteristics
   a. Mechanical details
   b. Resistance variation
   c. Starting currents
8. Starting efficiencies of different motors
   a. Code letters
   b. Measuring starting conditions

B. Laboratory Projects—15 hours
1. Motor-speed torque of:
   a. Squirrel cage
   b. Wound rotor
   c. Phase changers

DIVISION VIII. Three-Phase Synchronous Motor

A. Units of instruction—2 hours
1. Mechanical construction
2. Characteristics of operation
3. Excitation and starting

B. Laboratory projects—3 hours
Synchronous motor starting and "V" curves

DIVISION IX. Synchronous Converters

A. Units of instruction—1 hour
1. Construction
2. Characteristics
3. Starting and voltage regulation

B. Laboratory projects—3 hours
Synchronous converters—starting and operation

DIVISION X. Single-Phase Motors

A. Units of Instruction—3 hours
1. Split-phase motors
   a. Construction and uses
   b. Electrical circuits
   c. Response curves and cost
2. Capacitor motors
   a. Theory
   b. Capacitor start—capacitor run—capacitor sizes
   c. Response curves and uses
3. Repulsion motors
   a. Mechanical construction
   b. Electrical theory
   c. Response curves, cost, and use
   d. Repulsion start—induction run
   e. Repulsion start—repulsion run
4. Universal motors
   a. Theory
   b. Curves and uses

B. Laboratory projects: single phase motors—15 hours
1. Starting efficiency
2. Phase angles or start
3. Heat run
4. Speed torque curves
5. Phase changer

DIVISION XI. Minute Motors

A. Units of Instruction—1 hour
   1. Shaded pole motor
      a. Theory of operation
      b. Costs and use
   2. Make and break motors
      a. Theory of operation
      b. Cost and use
   3. Telechron clock motors
      a. Theory of operation
      b. Cost and use
   4. Single-phase synchronous (reluctance) motors—theory of operation

B. Laboratory projects—12 hours
   1. Minute motor—efficiency tests and operation
   2. Make-up—6 hours

Texts and References

Select one of the following books for a text. Others may be used as possible references.

BAILEY, B. F., *and* GAULT, J. S., *Alternating Current Machinery.* New York: McGraw-Hill Book Co.

BLUME, L. F., *Transformer Engineering.* New York: John Wiley & Sons.

DAWES, CHESTER L., *A Course in Electrical Engineering Vol. II.* New York: McGraw-Hill Book Co.

KRAENHENBUEHL, JOHN O., *and* FAUCETT, MAX A., *Circuits and Machines in Electrical Engineering.* New York: John Wiley & Sons.

REED, HENRY T., *and* CORCORAN, GEORGE F., *Electrical Engineering Experiments.* New York: John Wiley & Sons.

SEALEY, W. C., *Transformers, Theory and Construction.* Scranton, Pa.: International Textbook Co.

SISKIND, CHARLES S., *Induction Motors.* New York: McGraw-Hill Book Co.

VEINOTT, CYRIL G., *Fractional Horsepower Electric Motors.* New York: McGraw-Hill Book Co.

WOOD, W. S., *Theory of Electric Machines.* London: Butterworth Scientific.

E 272, Electrical Installation Planning

Hours Required

Class, 2; Laboratory, 0

Description

Methods and materials used in electrical installations and problems encountered in electrical construction work. Wiring materials including those in the National Electric Code.

Note: Although no laboratory is shown for this instruction, it would be desirable where possible to inspect selected examples of industrial installations.

Major Divisions

	Class hours
I. General Principles of Electrical Wiring	18
II. Industrial Wiring Requirements	16

DIVISION I. General Principles of Electrical Wiring—18 hours

1. Codes and laws governing electric installations
   a. Local codes and laws
   b. National Electric Code
   c. National Safety Code
2. Materials, fittings and devices
3. Circuits
   a. Power circuits
   b. Switch circuits
   c. Signal circuits
4. Over-current protection
5. Conductors
   a. Types
   b. Sizes
   c. Computing carrying capacity
   d. Computing voltage drop
6. Theory and practices of grounding
7. Wiring methods
   a. Open wiring
   b. Cable wiring
   c. Wiring in raceways
   d. Surface wiring
8. Branch circuits
   a. Computing number and size required
   b. Over-current protection
   c. Individual circuits
9. Feeders
   a. Computing size
   b. Over-current protection
10. Services
    a. Overhead
    b. Underground
    c. Service entrance installations
11. Load centers
12. Adequate wiring
13. Special circuits
14. Finishing
    a. Running circuits
    b. Installing switches and outlets
    c. Hanging fixtures
15. Old Work

DIVISION II. Industrial Wiring Requirements—16 hours

1. Computing industrial loads
2. Making layouts for industrial buildings
   a. Circuit layouts
   b. Conduit layouts
3. Industrial lighting
4. Industrial power circuits
5. Special problems in wiring
   a. Schools
   b. Stores
   c. Churches
   d. Theaters and motion picture houses
   e. Office buildings
   f. Factories
6. Industrial motor installation
   a. Motor circuits
   b. Motor control circuits
   c. Grounding practices
7. Hazardous locations
   a. Class I
   b. Class II
   c. Class III

8. Estimating
   a. Materials
   b. Labor

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

ABBOTT, A. L., *National Electrical Code Handbook.* New York: McGraw-Hill Book Co.

RITCHER, H. P., *Practical Electrical Wiring.* New York: McGraw-Hill Book Co.

UHL, DUNLAP, FLYNN, *Interior Wiring and Estimating.* (Residential and Industrial Publication). Chicago: American Technical Society.

G 213, Chemistry and Applications in Electricity

Hours Required

Class, 2; Laboratory, 3

Description

The course includes the basic principles of chemistry and application of these principles in industrial processes. Sources of raw materials useful in industry and the modification of these materials through changes in chemical and physical properties are considered.

Major Divisions

	Class hours	Laboratory hours
I. Fundamental Principles	1	6
II. The Atom: Its Structure and Behavior	2	3
III. Oxygen: Speed of Reaction	1	3
IV. Formulas and Equations	1	0
V. Hydrogen	1	3
VI. Valence	2	0
VII. Classification and Nomenclature of Compounds	2	3
VIII. Ionization	2	0
IX. Electrochemistry	2	6
X. Acids, Bases, and Salts, Hydrogen Ion Concentration	2	3
XI. Kinetic Molecular Theory and States of Matter	3	3
XII. Water and Solutions	1	0
XIII. Metallurgy. Oxidation and Reduction	3	6
XIV. Metals: Iron, Cobalt, and Nickel	1	0
XV. Carbon and Its Oxides	2	3
XVI. Organic Compounds: Hydrocarbons and Their Derivatives	3	6
XVII. Organic Compounds: Polymers	3	6
XVIII. Review	2	0

DIVISION I. Fundamental Principles

A. Units of instruction—1 hour
  1. Definitions and descriptions of: matter, energy, chemical and physical changes, properties, density, compounds, elements, metals, nonmetals, atoms, molecules
  2. Law of Definite Proportion and Law of Conservation of Matter and Energy
  3. The metric system of measurement

B. Laboratory projects—6 hours
  1. Practice in measuring various objects with metric rules, graduates, balances, and scales
  2. Density of water by use of Harvard trip scale and graduated cylinder
  3. Written laboratory report

DIVISION II. The Atom: Its Structure and Behavior

A. Units of instruction—2 hours
  1. The Bohr concept of the atom with an evaluation of its uses and limitation. Emphasis on the role of the outer electrons and some explanation of radio activity and nuclear energy
  2. Electrovalent and covalent compounds
  3. Valence: Molecular weights and formula weights

B. Laboratory projects—3 hours
  1. Use of triple beam balances and pipettes in determining density. Use of hydrometers with different scales, i.e., specific gravity, Baume, API, etc.
  2. Errors and percentage errors. Identification of metals from density determination
  3. Written laboratory report

DIVISION III. Oxygen: Speed of Reaction

A. Units of instruction—1 hour
  1. Properties, preparation, sources, and uses
  2. Acid anhydrides and basic anhydrides
  3. Combustion as oxidation
  4. Factors affecting rate of combustion

B. Laboratory projects—3 hours
  1. Stability of oxygen compounds, properties of oxygen and oxides
  2. Written report including equations for all reactions

DIVISION IV. Formulas and Equations

A. Units of instruction—1 hour
  1. Discussion and drill on writing formulas and equations
  2. Various meanings of formulas and interpretation of equations
  3. Percentage composition

DIVISION V. Hydrogen

A. Units of instruction—1 hour
  1. Sources, properties, production, and uses of hydrogen
  2. Displacement and displacement series
  3. Periodic table
    a. Classification of elements
    b. Physical and chemical behavior of elements as predicted from table

B. Laboratory projects—3 hours
  1. Examination of a great variety of metals and nonmetals for physical and chemical properties including, where practical, color, lustre, hardness, ductility, density, conductivities, and state at room temperature.
  2. Determine acidity or basicity of water solutions of oxides of various elements. Written report

DIVISION VI. Valence

A. Units of instruction—2 hours
  1. Relation of valence to atomic structure
  2. Use of valence in writing formulas
  3. Experimental determination of valence
  4. Electrovalence, covalence, coordinate valence. Drill and memorization of valences and formulas.

DIVISION VII. Classification and Nomenclature of Compounds

A. Units of instruction—2 hours
  1. Definitions and properties of acid, salts, and oxides
  2. Type reactions of acids, bases, salts, and oxides
  3. Naming of acids, bases, salts, and oxides

B. Laboratory projects—3 hours
  1. Measure conductivity of solution of acids, bases, and salts of same concentration
  2. Repeat at other concentrations including dry or 100 percent concentrations and on some covalent compounds including water
  3. Determine conductivity of one or two nonaqueous salt or acid solutions
  4. Determine effect on blue and red litmus and wide range pH paper
  5. Action on dried zinc, selected acids and bases. Taste and feel of dilute acid, base, and salt solutions. Written report

DIVISION VIII. Ionization

A. Units of instruction—2 hours
  1. Conduction in solution of acids, bases, salts and molten salts
  2. Colligative properties
  3. The Arrhenius ionization theory as explanation
  4. Debye-Huckel modifications
  5. Degrees of ionizations
  6. Neutralization and other reactions in aqueous solutions

DIVISION IX. Electrochemistry

A. Units of instruction—2 hours
  1. Electrolysis
  2. Faraday's laws
  3. Voltaic cells
  4. Electrode potentials and relation to displacement series
  5. Dry cells
  6. Storage batteries
  7. Electroplating

B. Laboratory projects—6 hours
  1. Electrolysis of water—copper electrodes
  2. Electrolysis of cupric sulfate solution with silver anode and iron cathode and with carbon electrodes
  3. Electrolysis of colorless potassium iodide solution containing phenolphthalein with carbon electrodes
  4. Chromium, nickel, and silver plating
  5. Written report

DIVISION X. Acids, Bases, and Salts, Hydrogen Ion Concentration

A. Units of instruction—2 hours
  1. Hydrogen ion concentration

2. Ionization of acids and importance of water
3. Polyprotic acids
4. Ionization of bases
5. Strength of acids, and bases: molalities and normalities
6. Hydrogen ion concentration and pH scale of measurement

B. Laboratory projects—3 hours
1. Determine pH of a number of acid, base, salt solutions and a few natural products such as saliva, vinegar, detergent solutions, etc., by use of short range indicator papers and by liquid indicator standards
2. Demonstrate use of glass electrode pH meter
3. Calculate hydrogen ion concentration and hydroxyl ion concentration of selected solutions from pH determination
4. Written report

DIVISION XI. Kinetic Molecular Theory and States of Matter

A. Units of instruction—3 hours
1. Gaseous states: pressure, pressure-volume relation, temperature-volume relations, diffusion, partial pressures
2. Kinetic theory applied to gases
3. Liquefaction, critical points
4. Liquid states: evaporation, condensation, heat of vaporization and condensation, boiling point, surface tension, viscosity, distillation
5. Kinetic theory applied to liquids
6. Solid state: freezing, melting, sublimation, heat of fusion
7. Crystalline and amorphous state
8. Kinetic theory applied to solids

B. Laboratory projects—3 hours
1. Galvanic couple and effect on rate of dissolving of acid on metal
2. Make and observe simple dry cell and lead storage battery
3. Determination of equivalent weight of copper by application of Faraday's law
4. Examine in detail an electric refrigerator identifying important mechanical parts
5. Use of tables in determination of suitable refrigerant
6. Interpretation of temperature pressure curves
7. Written report

DIVISION XII. Water and Solutions

A. Units of instruction—1 hour
1. Chemical properties of water hydrates
2. Solutions: types and classification
3. Dissolving, saturation, unsaturation, supersaturation
4. Temperature effects on dissolving
5. Solubilities
6. Concentrations
7. Distillation and distillation curves of volatile mixtures
8. Freezing points of solutions

DIVISION XIII. Metallurgy: Oxidation and Reduction

A. Units of instruction—3 hours
1. Bonding forces, physical properties
2. Alloys, simple phase diagrams
3. Occurrence
4. Minerals and ores, metallurgy
5. Chemical properties of metals
6. Metal oxides and hydroxides
7. Electron definition of oxidation and reduction

B. Laboratory projects—6 hours
1. Laboratory on ore concentration by flotation
2. Production of mercury by roasting cinnabar and heating oxide
3. Roasting and reduction of galena
4. Thermal decomposition of $CuCO_3$ and reduction of CuO
5. Essential parts and design of Bunsen burners, gas stove, welding torch
6. Determination of available temperatures, and how these are produced by changing activity and concentration of fuels and supporters of combustion used
7. Products of combustion
8. Examination of types of flames produced under various conditions
9. Written report

DIVISION XIV. Metals: Iron, Cobalt, and Nickel

A. Units of instruction—1 hour
1. Occurrence, metallurgy, properties of iron
2. Steel production and properties

DIVISION XV. Carbon and Its Oxides

A. Units of instruction—2 hours
1. Occurrence, forms, properties, uses
2. Coal, wood, oil, and gaseous fuels
3. Destructive distillation

4. Binary compounds especially carbon dioxide and carbon monoxide
5. Photosynthesis
6. Flames

B. Laboratory projects—3 hours
1. Perform destructive distillation on bituminous coal and soft wood
2. Identify gaseous, liquid and solid fractions
3. Run proximate analysis on soft coal
4. Written report

DIVISION XVI. Organic Compounds: Hydrocarbons and Their Derivatives

A. Units of instruction—3 hours
1. Hydrocarbons, names and structures, sources, and properties of first ten alkanes, nine alkynes, benzene, and toluene
2. Isomers, fractional distillation, thermal cracking, catalytic cracking, alkylation and reforming

B. Laboratory projects—6 hours
1. Fractional distillation of crude oil
2. Volatility, flash, and unsaturation tests on various fractions
3. Sweetening of crudes
4. Nomenclature, structure, properties, uses, sources of simple alcohols, ether, aldehydes, ketones, acids, amines, and halides
5. Production of various types of plastics
6. Examination of laboratory products and commercial sample for hardness, ductility, reaction toward heat, and solubility in various solvents

DIVISION XVII. Organic Compounds Polymers

A. Units of instruction—3 hours
1. Production, properties, reactions, nomenclature, uses
2. Fats, sugars, proteins, cellulose, rayon, dacron, nylon, natural and artificial rubbers and plastics

B. Laboratory projects—6 hours
1. Separation of commercial lacquers into components by steam distillation
2. Examination of water soluble solvent through a boiling point curve
3. Examination of water insoluble solvent through a boiling point curve
4. Make lacquer from ingredients provided and use on test panel
5. Make test panels of a sample of commercial lacquer
6. Test both panels for film hardness and resistance to various solvents
7. Written report

DIVISION XVIII. Review—2 hours

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

BADGER, WALTER T. *and* BANCHERO, JULIUS T., *Introduction to Chemical Engineering.* New York: McGraw-Hill Book Co.

BENSON, SIDNEY W., *Chemical Calculations.* New York: John Wiley & Sons.

HOLMES, HENRY N., *Introductory College Chemistry.* New York: The Macmillan Co.

LEIGHTON, ROBERT B., *Chemistry of Engineering Materials.* New York: McGraw-Hill Book Co.

PRUTTON, CARL, *and* MARON, SAMUEL H., *Fundamental Principles of Physical Chemistry.* New York: The Macmillan Co.

SORUM, CLARENCE H., *How To Solve General Chemistry Problems,* second edition. Englewood Cliffs, N.J.: Prentice-Hall Book Co.

SORUM, CLARENCE H., *Fundamentals of General Chemistry.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

WALTON, H. F., *Elementary Quantitative Analyses.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

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COURSE OUTLINES: SECOND YEAR, FOURTH SEMESTER

E 264, Industrial Electronics

Hours Required

Class, 3; Laboratory, 3

Description

Application of electronics to the control of power equipment. The basic circuits, control elements and hardware of controls are used to acquaint the student with circuit applications. The emphasis is on circuit theory and operation, limiting variables, and response characteristics of the typical industrial control equipment.

Major Divisions

	Class hours	Laboratory hours
I. Feedback Circuits	3	3
II. Electronic Timers	3	3
III. Thermonic Electronics	6	3
IV. Photoelectric Cell Devices	6	6
V. Industrial Power Conversion	3	3
VI. Electronic Controlled Power Machines	6	6
VII. Electronic Heating System Control	3	3
VIII. Transistors	6	12
IX. Servomechanisms	15	15

Division I.

A. Feedback Circuits—3 Hours
   1. Amplifier Response curves
   2. Corrections with feedback
   3. Cathode followers

B. Laboratory—3 hours
   Simplified feedback amplifiers

Division II.

A. Electronic Timers—3 hours
   1. Time delay circuits
   2. Counting circuits
   3. Industrial application

B. Laboratory—3 hours
   Basic timing and time delay circuits

Division III.

A. Thermonic Electronics—6 hours
   1. Induction heater hardware
   2. Induction heater circuits
   3. Diathermy machines
   4. Electronic welder controls
   5. Furnace controllers
   6. Combustion controls
   7. Electronic pyrometers

B. Laboratory—3 hours
   1. Circuit tracing diathermy or similar heat devices
   2. Testing operation of flame failure mock-ups

Division IV.

A. Photoelectric Cell Devices—6 hours
   1. Basic circuits
   2. Response curves of photo elements
   3. Photoelectric instruments and controllers
   4. Photo cell counting

B. Laboratory—6 hours
   1. Photoelectric cell response
   2. Photoelectric cell controlled devices

Division V.

A. Industrial Power Conversion—3 hours
   1. The thyratron and ignition tubes
   2. Wave shapes and loading effects
   3. Phase shift control of rectifiers

B. Laboratory—3 hours
   A.C. to D.C. convertors using thyratron phase shift controls

DIVISION VI.

A. Electronic Controlled Power Machines—6 hours
1. Motor with fixed speed—variable speed motor controllers
2. D.C. generator exciter controller
3. D.C. motor electronic controllers
4. A.C. motor speed controllers
5. A.C. motor reversing electronics
6. Slip-ring motor controllers

B. Laboratory—6 hours
1. Electronic drag cup motor controller
2. Electronic control of slip-ring controllers

DIVISION VII.

A. Electronic Heating System Control—3 hours
1. Basic heat sensing elements
2. On-off controllers and cycling
3. Inside-outside controllers

B. Laboratory—3 hours
Basic heat system controller

DIVISION VIII.

A. Transistors—6 hours
1. Transistor as element in electronics
2. Transistor types and characteristics
3. Transistor functions in amplifiers
4. The transistor amplifier
5. Response curves of transistor amplifiers
6. Transistor power amplifiers
7. Transistors in push-pull

B. Laboratory—12 hours
1. The transistor constants
2. Design a single-stage transistor amplifier
3. Assemble a single-stage transistor amplifier and test
4. Assemble a 3-stage transistor amplifier

DIVISION IX.

A. Servomechanisms—15 hours
1. Open- and closed-circuit principles with block diagrams
2. Problems of feedback; gain, time response, oscillations, error sensing
3. Servo control of D.C. motors
4. Servo control of A.C. motors
5. Mechanical servo units

B. Laboratory—15 hours
1. Operational test of heating—unit servo
2. Operational test of D.C. motor—servo controlled

Texts and References

Select one of the following as a text. Others may be considered as possible reference books.

ARNETT, F. A., *Practical Industrial Electronics;* New York: McGraw-Hill Book Co., Inc.

BENEDICT, R. RALPH, *Introduction to Industrial Electronics.* Englewood Cliffs, N.J.: Prentice-Hall Book Co.

COCKRELL, W. D., *Industrial Electronic Control.* New York: McGraw-Hill Book Co.

KLOEFFLER, ROYCE G., *Industrial Electronics and Controls.* New York: John Wiley & Sons.

Learning Electric and Electronics Experimentally. Vincennes, Ind.: Scientific Book Co.

E 274, Electrical Control Circuits

Hours Required

Class, 3; Laboratory, 3

Description

The principles and applications of electrical controllers are covered in this course, which serves as an introduction to automation. Devices for differentiation, integration and proportioning are studied in detail. Hardware and circuitry for AC and DC industrial control devices including contactors, starters, speed controllers, time delays, limit switches, and pilot devices. Application in the control of industrial equipment-motors, servo units, and motor-driven actuators. Laboratory demonstrations and field trips are provided. Prerequisite: E 215.

Major Divisions

	Class hours	*Laboratory hours*
I. Control Fundamentals	3	3
II. DC Acceleration and Speed Control Methods	3	3
III. DC Control Gear	3	3
IV. Adjustable Voltage Controllers	2	3
V. Two-Series Motor Drives	2	3
VI. Alternating Current Contactors and Relays	2	3
VII. Controls for Slip-ring Motors	3	3
VIII. Squirrel Cage Controls	3	3
IX. Single-Phase Motor Controllers	3	3
X. Various Controller Devices	3	3
XI. Typical Controlled Systems	24	21

DIVISION I. Control Fundamentals
- A. Units of instruction—3 hours
  1. Nomenclature, symbols, and definitions
  2. Pilot devices
  3. Contactors and relays
  4. Time delay methods
- B. Laboratory projects—3 hours
  DC contactors and their operation and mechanical construction

DIVISION II. DC Acceleration and Speed Control Methods
- A. Units of instruction—3 hours
  1. CEMF method
  2. Lockout contactors
  3. Voltage drop contactors
  4. Multicircuit timers
  5. Motor-driver timers
  6. Capacitor discharge method
  7. Face plate starters
  8. Drum type controllers
- B. Laboratory projects—3 hours
  D.C. starting methods

DIVISION III. DC Control Gear
- A. Units of instruction—3 hours
  1. Resistors
     a. Field discharge wire-wound Thyrite
     b. Sizing resistors
  2. Field failure protection
  3. Reversing rotation
  4. Plugging
  5. Speed control by field resistors
  6. Decelerating relay
  7. Motor driven rheostats
  8. Amplidyne
- B. Laboratory projects—3 hours
  1. DC Field protection
  2. DC Speed control

DIVISION IV. Adjustable Voltage Controllers
- A. Units of instruction—2 hours
  1. Basic system—single-motor controlled
  2. Multiple motor controls

3. Synchronizing motor drives
B. Laboratory projects—3 hours
Adjustable voltage speed control of a compound motor

DIVISION V. Two-Series Motor Drives
A. Units of instruction—2 hours
1. Basic system
2. Braking
3. Lowering controllers
4. Transition methods
5. Drum switching
6. Speed-torque curves and calculations
B. Laboratory projects—3 hours
1. DC starters
2. Drum controllers

DIVISION VI. A.C. Contactors and Relays
A. Units of instruction—2 hours
1. Shading poles and noise
2. Series relays
3. Overload devices
a. Magnetic
b. Thermal
4. Phase failure
5. Phase reversal
B. Laboratory projects—3 hours
Basic AC controllers and relays

DIVISION VII. Controls for Slip-Ring Motors
A. Units of instruction—3 hours
1. Timing relays operated by starting devices
2. Inductive time delays
3. Capacitor time delays
4. Series relays
5. Face plate controller
6. Drum controllers
7. Frequency relays
8. Calculations of accelerating time
9. Kraemer system
10. Scherbin's system
B. Laboratory projects—3 hours
AC slip-ring motor controller

DIVISION VIII. Squirrel Cage Controls
A. Units of instruction—3 hours
1. Auto-transformer starters
a. Compensator
b. Korndorfer
2. Resistor starters
3. Part-winding starters—wye-delta starters
4. Multiple speed controllers. Different windings
5. Induction generators
6. Concatenation of motors
B. Laboratory projects—3 hours
1. Induction generators
2. Induction motor starters

DIVISION IX. Single-Phase Motor Controllers
A. Units of instruction—3 hours
1. Capacitor motor controllers and arrangements of capacitors
2. Repulsion motors
3. Auto-transformer controller
B. Laboratory projects—3 hours
Single-phase motor starters and speed controllers

DIVISION X. Various Controller Devices
A. Units of instruction—3 hours
1. Feedback systems
a. Block diagram and error systems
b. Troubles of feedback
(1) Gain
(2) Oscillation
2. Basic sensing devices
a. Thermocouples
b. Tachometers
c. Differential transformers
d. Photoelectric
e. Saturable transformers and magnetic amplifiers
f. Electronic speed regulators
B. Laboratory projects—3 hours
Basic sensing devices

DIVISION XI. Typical Controlled Systems
A. Units of instruction—24 hours
1. Photoelectric controlled systems
a. Measuring devices
b. Alarm systems
c. Motored devices
2. Level controllers
a. Float controllers
b. Magnetic coupled controllers
c. Remote controlled
3. Temperature control systems
a. Thermocouple potentiometer controllers
b. Contact galvanometer potentiometer controller
c. Resistance—thermometer controller

4. Electrical control of fluid flow
   a. Electromagnetic valves and control methods
   b. Motor driven valves and control methods
   c. Servo-motor controlled valves and systems
   d. Electronic controllers and systems
5. Electrical telemetering as a control system
   a. Variation of electrical quantities
   b. Null balance method
   c. Electrical synchronizing
   d. Impulse selection
6. Electro-mechanical system
   a. Transducers as controllers
   b. Magnetic tape controllers
   c. Sequence switching controller
7. The amplidyne controlled system
   a. The amplidyne generator
   b. Voltage regulation by the amplidyne
   c. Thermotrol motor controller
8. Lighting controllers
   a. Saluable reactors
   b. Servo-operators
   c. Thyratron controllers

B. Laboratory projects—21 hours

Laboratory projects will be determined by the selection of systems that are available for study. Wherever possible it is recommended that field trips be taken and reported by the students.

Texts and References

Select one book from the following list for a text. Others may be used as references.

HARWOOD, P. B., *Control of Electric Motors.* New York: John Wiley & Sons.

JONES, R. W., *Electric Control Systems.* New York: John Wiley & Sons.

JAMES, H. D., *and* MARKLE, L. E., *Controllers for Electric Motors.* New York: McGraw-Hill Book Co.

E 284, Electrical Power Systems—In-Plant Distribution (With Utility Systems Option)

Hours Required

Class, 3; Laboratory, 3

Description

A study of the design, operation and technical details of modern power distribution systems including generating equipment, transmission lines, plant distribution, and protection devices. System load analysis, rates, and power economics are studied.

Note: The course outline is organized so that a choice in emphasis between utility systems and plant distribution systems must be made to stay within the time allotted. If the utility option is desired, the material in Division VI, Plant Distribution should be eliminated or only briefly covered. If the desire is concentration on Plant Distribution, Division VII, VIII, and IX should be eliminated or given only very brief survey coverage.

Major Divisions

	Class hours	Laboratory hours
I. Power Plants	3	-------
II. Plant Operation	4	-------
III. Switch Gear	6	-------
IV. Circuit Breakers	4	-------
V. Short Circuit Currents	5	-------
VI. Plant Distribution	9	3
VII. Transmission Lines	2	-------
VIII. Transmission Line Calculations	6	-------
IX. Distribution Systems	4	-------
X. Lightning Protection	2	-------
XI. Relays	12	-------
XII. Economics of Electric Service	4	-------

Division I. Power Plants

- A. Units of instruction—3 hours
  1. Steam plants
     - a. Mechanical layouts
     - b. Growth history
     - c. Location
     - d. Fuels
     - e. Cost
  2. Hydraulic plants
     - a. Mechanical components and types
     - b. Limiting factors
     - c. Operational features
  3. Diesel plants
     - a. Mechanical aspects
     - b. Economic uses
     - c. Limiting features
     - d. Fuel choices
     - e. Locomotive uses
  4. Gas turbine plants
     - a. Mechanical construction
     - b. Economic uses
     - c. As topping units
     - d. Locomotive prime movers
  5. Atomic plants
     - a. Theory of operation
     - b. Types of plants
     - c. Future developments

Division II. Plant Operation

- A. Units of Instruction—4 hours
  1. Load graphs
     - a. Types of graphs
       - (1) Daily
       - (2) Weekly
       - (3) Monthly
       - (4) Yearly
     - b. Data and use of graphs
       - (1) Demand
       - (2) Plant factors
       - (3) Load factors
       - (4) Utilization factors

2. D.C. generators as exciters
   a. Excitation circuits
   b. Common exciters
   c. Unit exciters
   d. Emergency units
      (1) Steam driven
      (2) Gas driven
      (3) Batteries
3. Common voltage regulators
   a. Silverstat
   b. Rocking drum
   c. Diactor
   d. Amplidyne
   e. Electronic
4. Plant electrical layouts and circuit breaker systems
   a. Single bus—single circuit breaker
   b. Double bus—single circuit breaker
   c. Double bus—double circuit breaker
   d. Ring bus system
   e. Low voltage and high voltage bus

DIVISION III. Switch Gear

A. Units of instruction—6 hours
   1. Switch boards
      a. Materials—slate, ebonite, steel
      b. Mounting
      c. Usual meters and relays
         (1) Distribution
         (2) Generators
         (3) Exciters
      d. Wiring methods
         (1) Wire types and sizes
         (2) Procedure and color coding
         (3) Circuits on board
   2. Switchgear and switch operators
      a. Direct manual
      b. Remote manual
         (1) Arrangement and adjustment of rods and bell cranks
         (2) Circuit breaker mounting methods
            (a) Racks
            (b) Walls
         (3) Trip circuits
      c. Electric remote switchgear
         (1) Operational energy
         (2) Motors, solenoids, thrusters
         (3) Pneumatic and air compressors
      d. Types of outdoor switchgear
         (1) By-pass switches
         (2) Disconnects
         (3) Fused disconnects
         (4) Ganged switches
         (5) Motor operated switches
      e. Switchyard arrangements
         (1) Wooden structures
         (2) Steel structures
         (3) Pedestal-type installations
         (4) Low voltage and high voltage busses
         (5) Operational procedures and safety protection

DIVISION IV. Circuit Breakers

A. Units of instruction—4 hours
   1. Operators for circuit breakers
      a. Gravity
      b. Spring loaded
      c. Pneumatic
   2. Arc extinguishing methods
      a. Blow out coils
      b. Oil immersed
      c. De-ion principle
      d. Explosion chambers
      e. Air blast
      f. Oil blast
   3. Contact details on each of the following
      a. Butt contact
      b. Bayonet contact
      c. Wedge contact
      d. Normal current or arcing contact
   4. Mountings and operators
      a. Vertical breakers of OCB
      b. Horizontal breakers of OCB
      c. Types of operators
         (1) Gravity
         (2) Spring
         (3) Pneumatic
   5. Ratings and capacity
      a. Voltage rating
      b. KVA carrying
      c. Interrupting KVA
      d. Time element of breaking

DIVISION V. Short Circuit Currents

A. Units of instruction—5 hours
   1. Nature of short circuits
      a. Types and frequency
      b. Transient currents
      c. Steady state short circuit currents
      d. Zero sequence short circuit currents
   2. Mathematics of short circuit currents
      a. Using the ohms reactance
      b. Using the per unit reactance

c. Using the percent reactance
d. Data from curves
3. Limiting reactors
a. Mechanical construction
b. Line reactors
c. Generators reactors
d. Grounding reactors
e. Grounding resistors
4. Sample problems on short circuiting
a. Single lines
b. One generator—1-line
c. System shorts

DIVISION VI. Plant Distribution

A. Units of Instruction—9 hours
1. Plant loads and lighting
a. Plant load graphs
b. Grounding practices
c. Calculations of load center
d. Motor and lighting power centers
e. Circuit breakers, fuses, and their coordination to plant loads
f. Service entrances, conduit, channels, ducts, etc.
g. Voltage drops, their calculations using graphs
h. Capacitor switching
2. Plant electrical maintenance
a. Plant electrical safety
b. Voltage regulation
c. Capacitor installation and calculations
d. Electrical load surveys
e. Plant electrical inspection

B. Laboratory projects—3 hours
1. Load center calculations and plant load calculations
2. Various types of power entrance designs
3. Voltage drop calculations, capacitor calculations and time control plan

DIVISION VII. Transmission Lines

A. Units of instruction—2 hours
1. Location limitations
a. Geographical
b. Present and future loads
c. Influence on present systems
d. Economics
2. Systems
a. Voltage, KVA limitations
b. Specific systems taken from industry
3. Construction details
a. Poles
(1) Wooden
(2) Steel
(3) H frame
(4) Gaying
(5) Silver crossings
b. Conductors
(1) Solid copper
(2) Stranded copper
(3) Copper weld
(4) A.C.S.R.
c. Hardware
(1) Pins
(2) Insulators
(3) Lightning arrestors
(4) Sectionizing switches
(5) Grounding practice

DIVISION VIII. Transmission Line Calculations

A. Units of instruction—6 hours
1. Economic size lines
a. Yearly cost formula
(1) Costs of money
(2) Costs of maintenance
(3) Loss cost
b. Future development
2. Skin effect
a. Cause
b. Frequency influence
c. Formula and application
3. Lines reactance
a. Cause and effect
b. Formula for line reactance
c. Application to specific lines
4. Line capacitance
a. Cause and effect
b. Formula for line capacitance
c. Application to specific lines
5. Line calculations
a. Definition of short lines
b. Loss and regulation using short line formulas
c. Use of curves for line regulation and loss
d. Long line calculation
(1) Using equivalent network
(2) Using artificial lines
(3) Line performance from graphs
6. Corona
a. Nature and effect of corona
b. Critical voltage formula
c. Preventative means
7. Line mechanics
a. Sag causes and line tension

b. Methods of measuring sag
   (1) Tape
   (2) Sag boards
   (3) Tension measurement
   (4) Timing reflected waves
c. Icing
   (1) Geographical influence
   (2) Preventative means
d. Transposition
   (1) Practices
   (2) Influence on conductors
   (3) Influence on adjacent circuits
   (4) Influence on telephone and fence lines

8. Stability
   a. Reasons for stability of systems
   b. Factors that influence stability
   c. Stability limiting factors
   d. Stability improvement

DIVISION IX. Distribution Systems

A. Units of instruction—4 hours
   1. Distribution systems
      a. Tree system
      b. Feeder and main
      c. Network
      d. Loop
      e. Lines
      f. Arc circuits
   2. Underground
      a. Economics and problems
      b. Ducts
      c. Underground substations
      d. Cables
   3. Distribution transformers
      a. Types
      b. Protection
      c. Installation practices
      d. Loading
      e. Voltage regulation

DIVISION X. Lightning Protection

A. Units of instruction—2 hours
   1. Nature of surges
      a. Cause
      b. Voltage amplitude
      c. Current amplitude
      d. Frequency
   2. Grounding practices for protection
      a. Transformers
      b. Lines
      c. Arrestors
      d. Gaps
      e. Overhead static wires
      f. Cables

DIVISION XI. Relays

A. Units of instruction—12 hours
   1. Basic types
      a. Time delay
      b. Instantaneous
      c. Inverse time
   2. Basic induction relay (over current)
      a. Construction
      b. Circuits
      c. Pickup current
      d. Lever setting
   3. Over current protection of equipment
      a. Straight over current
      b. Directional over current
      c. Differential protection
      d. Percentage differential
      e. Backup protection and zones
      f. Relay and fuse co-ordination
      g. Thermal protection
      h. Pilot wire
      i. Carrier current protection

DIVISION XII. Economics of Electric Service

A. Units of instruction—4 hours
   1. Government regulations
      a. National
      b. State
      c. City
      d. Monopoly nature
      e. Government ownership
   2. Rate making
      a. Straight rates
      b. Block rates
      c. Demand and energy charges
      d. Lighting and power rates
      e. Costs that influence rates
   3. Depreciation
      a. Functional
      b. Physical
      c. Depreciation calculations and values
      d. Forecasting depreciation
   4. Taxes
      a. Plant evaluation for tax purposes
      b. Average taxes and influence on costs
   5. Factors influencing KWH costs
      a. Fuel
      b. Labor
      c. Money costs
      d. Superintendency
      e. Overhead

Laboratory

The laboratory work consists of planning and designing electrical installations—not to be confused with construction or electrical machine design. The projects are assigned for designing of a particular project. Selection of component equipment is made from catalog descriptions or from the study of a specific installation in service. The design report should contain a complete drawing, necessary detail sheets, parts lists giving catalog descriptions, number of units, manufacture, and price, if available.

This laboratory work may not lend itself to close correlation of theory and laboratory time schedules. Availability of commercial installations for study will allow alternate projects. Some suggested alternates are: Electrical ship propulsion; Diesel electric plant; Elevator controls, etc.

Texts and References:

Select one of the following books for a text. Others may be used as references.

Electrical World (monthly publication). New York: McGraw-Hill Book Co.

KIMBARK, E. W., *Electric Transmission of Power and Signals*. Englewood Cliffs, N.J.: Prentice-Hall Book Co.

KNOWLTON, A. E., *Standard Handbook for Electrical Engineers*. New York: McGraw-Hill Book Co.

SKROTZKI, BERHARDT G. A., *Electric Generation—Diesel Stations*. New York: McGraw-Hill Book Co.

———., *Electric Generation Steam Stations*. New York: McGraw-Hill Book Co.

———., *Electric Transmission and Distribution*. New York: McGraw-Hill Book Co.

TARBOUX, J. G., *Electric Power Equipment*. New York: McGraw-Hill Book Co.

THUESEN, H. G., *Engineering Economics*. Englewood Cliffs, N.J.: Prentice-Hall Book Co.

E 294, Operating Problem Analysis

Hours Required

Class, 2; Laboratory, 6

Description

A study is made of the proper procedures to be used in testing for troubles of electrical systems and their correction. The methods used in setting up and supervising a program of preventive maintenance, trouble-shooting, equipment receiving, data recording, and cost accounting are also studied.

Major Divisions

	Class hours	*Laboratory hours*[1]
I. Three-Phase Motors—Symptoms, Causes, and Remedies	6	-------
II. Single-Phase Motors	5	-------
III. D. C. Machines	2	-------
IV. Transformers—Troubles and Remedies	2	-------
V. Troubles of Air and Oil Circuit Breakers	2	-------
VI. Operation, Maintenance, and Troubles of Relays	2	-------
VII. Industrial Motor Control	3	-------
VIII. Motor Specifications	1	-------
IX. Lightning Arrestors	1	-------
X. Troubles of Regulators	1	-------
XI. Storage Battery Maintenance	1	-------
XII. Plant Power Factor Control	2	-------
XIII. Maintenance Scheduling	2	-------
XIV. Load Surveys	2	-------
XV. Plant Lubrication	2	-------

[1] See explanation of laboratory work at the end of this outline.

DIVISION I. Three-Phase Motors—Symptoms, Causes and Remedies

A. Units of instruction—6 hours
1. Induction Motors
   a. Grounds
   b. Short circuits
   c. Improper connection
   d. Improper voltage
   e. Bearings
   f. Ventilation
   g. Winding and insulation
2. Synchronous Motors. Troubles and cures

DIVISION II. Single-Phase Motors

A. Units of instruction—5 hours
1. Winding check
   a. Opens and shuts
   b. Insulation checking (hi-pot)
2. Centrifugal switches
   a. Faults
   b. Types
3. Capacitors
   a. Sizing
   b. Checking
4. Brushes and Commutators
   a. Care
   b. Regular maintenance
   c. Repair
5. Winding and insulation
   a. Winding methods
   b. Types of insulation
6. Block testing
   a. Starting Torque
   b. Running Torque
   c. H. P. output

DIVISION III. Direct Current Machines—Symptoms, Causes, and Remedies

A. Units of instruction—2 hours
1. Grounds and shorts
   a. Checks
   b. Repair methods
   c. Rewinding

2. Brushes and commutators
   a. Routine maintenance
   b. Rewinding procedure
   c. Brush hardness and fitting
   d. Under cutting
3. Heating
   a. Causes
   b. Checks
   c. Auto protection

DIVISION IV: Transformers—Trouble and Remedies

A. Units of instruction—2 hours
1. Three-Phase banks
   a. Load checking
   b. Bushing care
   c. Oil sampling
   d. Turns-ratio checks
2. Spare transformers
   a. Proper storage
   b. Checking before energizing
3. Overheating
   a. Causes
   b. Heat checks
   c. Alarm Methods
4. Oil testing
   a. Potential
   b. Water
   c. Acidity
5. Megger
   a. Use of instrument
   b. Proper M
   c. Possible cures for low readings
6. Hi-pot and turns-ratioing
   a. Instrument use
   b. Proper values
   c. Rewinding
7. Care and maintenance

DIVISION V. Troubles of Air and Oil Circuit Breakers

A. Units of instruction—2 hours
1. Blades and contacts
   a. Types
   b. Arc tips
   c. Maintenance
2. Bushings
   a. Dry
   b. Oil filled
   c. Condenser
3. Operators
   a. Spring loaded
   b. Gravity
   c. Pneumatic

DIVISION VI. Operation, Maintenance, and Troubles of Relays

A. Units of instruction—2 hours
1. Adjustments and tests of induction and instantaneous relays
   a. Adjustable elements
   b. Testing
   c. Repair
2. Relay curves
   a. Connecting
   b. Interpreting results
3. Relay connections
   a. Circuit recoding
   b. Mechanical wiring
   c. Trouble-shooting
4. Use of phase-angle meters and cycles counters
   a. The instruments
   b. Use of instruments

DIVISION VII. Industrial Motor Control

A. Units of instruction—3 hours
1. Contactors and contacts
   a. Types
   b. Maintenance
   c. Repair
2. Noise and excessive heating
   a. Cause
   b. Correction
3. Proper sequence testing
   a. The sequence charts
   b. Locating malfunction parts
4. Wiring diagram trouble-shooting

DIVISION VIII. Motor Specifications

A. Units of instruction—1 hour
1. Frequency of starting
   a. As determined by load
   b. As restricted by supply
2. Voltages
   a. Commercial supply
   b. Special applications
3. Motor installations
   a. Dry operating conditions
   b. Moisture problems
   c. Wet operation

4. Method of reduced voltage operation
    a. Tapped transformers
    b. Resistor control
    c. Auto transformers
5. Motor loads
    a. Steady conditions
    b. Variable loads
6. Inrush currents
    a. Permissible conditions
    b. Troubles from abnormal conditions
    c. Corrections for unsound conditions

DIVISION IX. Lightning Arrestors

A. Units of instruction—1 hour
1. Types
    a. Distribution type
    b. Transmission types
2. Checks
    a. Proper installation
    b. Proper breakdown
    c. Proper applied voltage
3. Troubles, and reasons for failures
    a. Reasons for failures
4. Testing
    a. Meggohmer
    b. Hi-pot

DIVISION X. Troubles of Regulators

A. Units of instruction—1 hour
1. Maintenance
    a. Routine checks
    b. Tear downs
2. Trouble shooting
    a. Controllers
    b. Step type regulators
    c. Induction regulators

DIVISION XI. Storage Battery Maintenance

A. Units of instruction—1 hour
1. Testing different types
    a. Lead-lead acid
    b. Edison cells
    c. Cadmium
2. Charging methods
    a. Controlled condition
    b. Automatic control
    c. Floating types
3. Cleaning and maintenance
    a. Routine care
    b. Equalizing charge
    c. Ventilation

DIVISION XII. Plant Power Factor Control

A. Units of instruction—2 hours
1. Checking
    a. Meters required and their use
    b. Proper procedures
    c. Interpreting and reporting results
2. Corrections
    a. Static capacitors
    b. Dynamic capacitors
    c. Synchronous devices
3. Economics
    a. Cost accounting
    b. Life estimates
    c. KWH cost

DIVISION XIII. Maintenance Scheduling

A. Units of instruction—2 hours
1. Timing
    a. Factors influencing timing inspections
    b. Scheduling with others
    c. General practices
2. Maintenance costs
    a. Record keeping
    b. Down time costs
    c. Economics

DIVISION XIV. Load Surveys

A. Units of instruction—2 hours
1. Survey procedures
2. Survey instruments
    a. Types of instruments
    b. Use of instruments
3. Reporting surveys
    a. Data
    b. Graphs and curves
    c. Conclusions

DIVISION XV. Plant Lubrication

A. Units of instruction—2 hours
1. Lubrication grades
    a. Viscosity
    b. Operating temperatures
    c. Base
2. Lubrication for bearings
    a. Lubrication methods
    b. Lubrication cooling
3. Chain drives
    a. Proper lubricants
    b. Lubrication methods

4. Treating and cleaning lubricating oil
   a. Proper lubricants
   b. Oil cleaners
   c. De-acidifiers
5. Inspection
   a. Visual
   b. Acids tests
   c. Flash points tests

Laboratory

A study of the malfunctions of electrical equipment, proper testing to determine sources of trouble, and trouble-shooting procedures. In the laboratory the students work individually on small equipment and in teams on larger equipment. The students work on "live" work as it comes into the lab. Each student should wind one fractional horsepower motor and assist with the rewinding of one three-phase motor. The remainder of the time is assigned on equipment as available. Laboratory organization is on an industrial basis. The students function as cost accountants, estimators, supervisors, troubleshooters, repairmen, etc. The laboratory instructor functions as a consultant for this course.

Texts and References

Select one of the following books as a text. Others may be used as references.

STAFFORD, H. E., *Troubles of Electric Equipment.* New York: McGraw-Hill Book Co.

JOHNSON, R. E., *Electrical Construction Cost Manual.* New York: McGraw-Hill Book Co.

ROSENBERG, ROBERT, *Electric Motor Repair.* New York: McGraw-Hill Book Co.

Electric Construction and Maintenance (monthly periodical). New York: McGraw-Hill Book Co.

APPENDIXES

APPENDIX A—Sample Instructional Materials

Instructional material for electrical technology should be designed to make the best possible use of available laboratory equipment. Very little published material in the form of workbooks or laboratory experiments is available. Textbooks are obtainable for the classroom work but material for demonstration and project work must be designed and prepared by instructional personnel experienced in the field of electrical technology. This material should, in general, be designed to serve as a guide in the learning process. A significant amount of the conclusions and results to be obtained should be left to student resourcefulness.

Typical Material for a Unit of Instruction

A full-time technical instructional program gains great strength from coordinated learning activities. Such activities include classroom instruction, directed study, demonstrations, examinations, problems, laboratory experiences, and reports. One of the basic steps of the learning process is the attack. The multiple approach method of attack is illustrated here by section *5* of E *215*, Alternating Current Machinery.

- Classroom lecture outline
- Reading assignment
- Problem assignment
- Laboratory projects
- Examination

Additional Instructional Material

Much of the work done in the laboratory can be designed to be completed within a single laboratory period of from two to three hours. Two examples of this type of project are shown, namely "The Sweep Generator" and "Multimeter Design and Construction." Instruction sheets for this type of exercise need not be detailed. Where only minimum instructions are given, the student will be required to participate in the planning of the project—an effective teaching technique in advanced courses.

Sample Laboratory Report

The formal laboratory report is an extremely effective part of the teaching and learning process. It is a form of recitation that demands an organized systematic approach and leads to a logical conclusion. Its educational value goes well beyond the absorption of facts and technical understanding. If properly used, it can promote straight thinking; it will strengthen the skills of communication and it can develop that most important of all motivation factors, personal pride.

The form suggested for the formal laboratory report follows accepted practices of technical reporting. It should be made clear to the student that the detailed information in the report is equal in importance to results and conclusion. A sample report is included to illustrate the value of careful marking and grading.

Text and Reference Material

The textbooks suggested for each course in this curriculum represent a range of depth in the mathematical treatment of the subject. The final selection of text materials will normally be made by those who teach the subject matter of the curriculum. Men with industrial experience are prone to select those textbooks that treat well the areas closest to their experience. Some instructors may lean too heavily on a text in order to simplify and standardize the instruction. Nevertheless, good textbooks and reference material are indispensable in formal classroom instruction.

In general, references should provide both a simplified exploration of the subject being studied and an extensive treatment for special reports.

Sample Instruction Units

Teaching Guide

E 215 Alternating Current Machinery

Topic: Special Transformers

Lecture Time: Two 50 minute periods
Laboratory Time: Two 3 hour periods
Quiz Time: 15 minutes
Outside Study: 6 hours (minimum)

Lecture Outlines

LECTURE 1: Special Transformers
Reference: Dawes, *Electrical Engineering*, Vol. II, page 285, paragraph 170; page 299, paragraph 177.

551292 O—60——6

Bailey & Gault, *Alternating Current Machinery*, page 28–30, 52.

Standard electrical engineers handbook.

Visual Aids: 1. Auto transformer using one coil from Crow demonstrator and lamp.

2. Tap changing, use Variac and tap changing from salvage distribution transformer. Opaque projector for automatic tap changer study.
3. Constant current transformer.
   a. Opaque projector.
   b. Crow demonstrator by moving secondary up and down.

Part I. Auto transformers
1. Turns ratio to voltage coil
2. As a step down voltage divider
3. Advantages of using auto transformers
   (a) Low voltage ratio transformation
   (b) Weight
   (c) Foundation requirements
   (d) Efficiency
4. Danger of auto transformers on high ratio transformation.
5. Power flow diagram
6. Vector diagram
7. Auto transformer as a step up transformer

Part II. Tap changing transformers
1. Anti-short coils and circuit diagram
2. Manual tap changers
3. Automatic controls

Part III. Constant current transformers
1. Street lighting circuits
2. Advantages of constant current series circuits
3. Series circuit fuse gaps in lamps
4. Construction and operational characteristics of constant current transformers
5. Dangers of series lighting circuits

Reading Assignment: Dawes, *Electrical Engineering*, Vol. II, paragraph 178, 179, and 202. Bailey and Gault, page 154.

Problem Assignment: Work problems No. 326 & 327, page 664, Dawes

LECTURE 2: Special Transformer—(continued)

Reference: See previous reading assignment

Visual Aids: 1. Instrument transformer. Opaque projector using catalog material of installations

2. Induction regulator. Opaque projection of cross section of induction regulator. Show automatic controls.

Part IV. Instrument Transformers
1. Problems and dangers of high voltage metering
2. The potential transformers
   (a) Wound and capacitor types
   (b) Indoor and outdoor uses
   (c) Ratio of transformation
   (d) Volt-ampere loading rating
   (e) Meter scaling, checking, and fusing
3. The current transformer
   (a) Wound and through types
   (b) Indoor and outdoor uses
   (c) Ratio of currents
   (d) The current transformer used for potential isolation
   (e) Dangers of opening current transformer
   (f) Meter scaling
   (g) CT circuit and when to short circuit

Part V. Induction voltage regulators
1. Theory of rotating secondary coil
2. Need for voltage regulation equipment
3. Connections and theory of regulators
   (a) Three phase
   (b) One phase
   (c) Amortisseur windings
4. Automatic rotating device and contact making voltmeter
5. Loads, KVA permitted, and protection for "no incoming voltage."

Reading Assignment: Dawes, *Electrical Engineering*, Vol. II, paragraphs 102–107.

Bailey & Gault, Pages 57–73.

Problem Assignment: Turn in answers to questions 41, 42, 43, and 44, page 661 of Dawes. Work problem #335, Dawes.

Laboratory I

Topic: Auto transformers

Equipment Required:

1 standard two winding 440–220–110 volt transformer
1 voltmeter 0–300 volts AC
1 wattmeter
1 ampere ammeter
Assorted lamps, lamp bases, and load resistors
Source 110 volt—220 volt power—60 cycles AC

Reference: Dawes, "Electrical Engineering," paragraph 120, Pages 285–288

Procedure: Use only X_1, X_2, X_3, and X_4 of conventional two windings transformer as auto transformer. Caution H_1, H_2, and H_3, H_4, are at rated voltage during experiment.[1]

1. Connect auto transformer as shown below and read all voltages, currents, and watts.
2. Connect load of lamps (or resistor bank) to bring transformer current to rated value. Record input watts, volts, amps, and output volt, and amps. Draw vectors and check calculated incoming line current with value on meter. Note discrepancies.
3. Connect step down 220–110 volts as shown and take no-load readings.
4. Load transformer with 110 volt bulbs (or resistance bank) to rated values. Record primary volts, amps, output volts, and amps. Draw vectors.

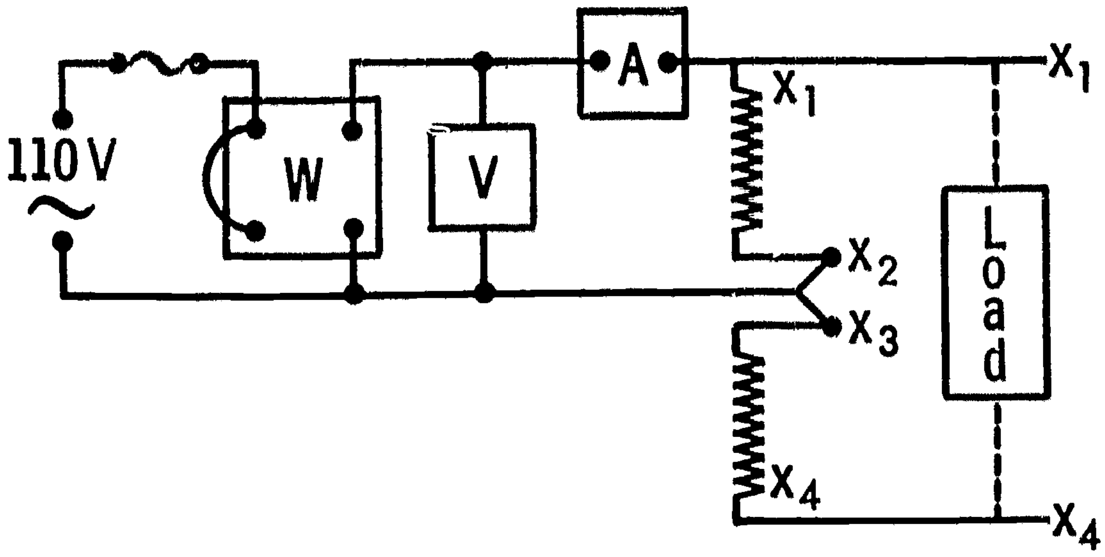
Report: Formal report required.

Data: All vectors to be scaled and computed accurately. Compare vectors A to C and B to D. Compare no-load vectors.

Discussion: Cover theory of operation, advantages, and disadvantages of using auto transformers. Compare cost as obtained from manufactors catalog. Compare installation cost if available. Compare freight costs.

Time: Report due 1 week from date of experiment.

[1] See Figure 1.



Record charging current data:

Volts ____________

Amperes ____________

Watts ____________

Power factor ____________

P.F. angle ________ °lag

Draw vector

EQUIPMENT FOR EXPERIMENT AUTO TRANSFORMER'S LABORATORY I

Laboratory II

Topic: Induction Regulator

Equipment Required:

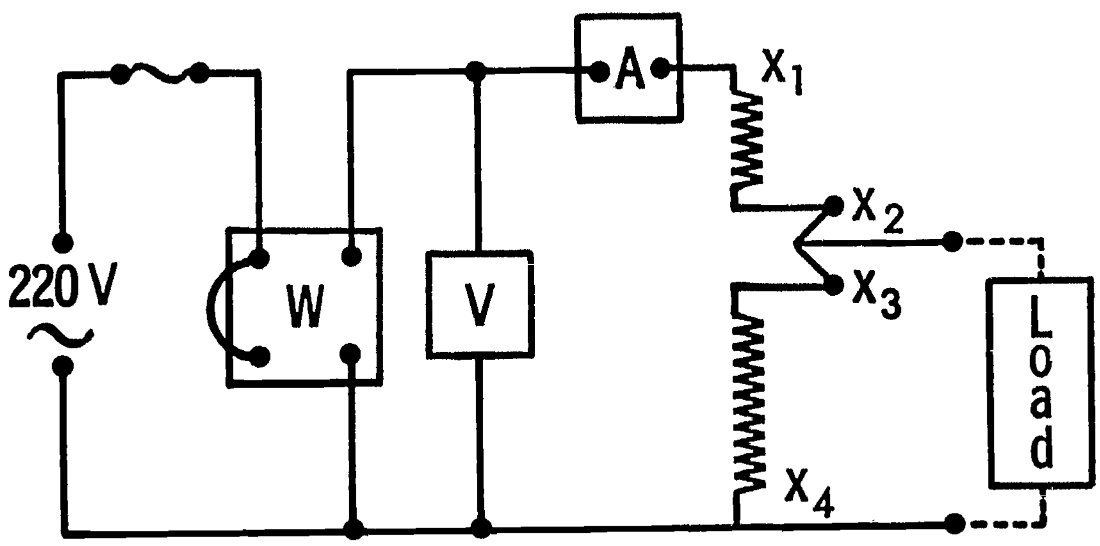
1 induction voltage regulator
1 A.C. voltmeter
Source of proper power supply

Reference:

Dawes, *Electrical Engineering*, Vol. II, pages 358 and 359.
Standard Electrical Engineering Handbook.
Blumes, *Transformer Engineering*.

Procedure:

1. Examine equipment. Rotate 180° and check mechanical movement.
2. Energize and measure voltages for volts, output volts, and induced volts. Draw vector diagram for three readings. Plot complete curve of output volts by degrees rotation.
3. Sketch cross section of regulator and indicate parts. (May use manufacturers' literature.)
4. Compare difference of theory of operation of 1 phase and 3 phase regulators.
5. From reference material submit a circuit diagram of electrical controls of a regulator, with an explanation of its operation.
6. Submit all results in an informal report one week from date of experiment.



Record values and draw vectors:

Volts ____________

Amperes ____________

Watts ____________

Power factor ____________

P.F. angle ________ °lag

EQUIPMENT FOR EXPERIMENT LABORATORY II

Examination Covering Part IV

Time: 25 Minutes

1. Three systems incorporating autotransformers may be used to supply 120 volt services to a customer from a 2400 volt supply. From an engineering viewpoint, discuss these three systems.
2. A customer is purchasing 2400 volt three phase delta connected power using conventional 120 volt-5 ampere meters. Determine the proper meter multipliers and shunts to be used for voltmeter, ammeter, wattmeter, and kilowatt hour meter. The maximum load to be 150 KVA.
3. An induction regulator is rated at 10% buck or boost, 2400 volts, single phase and for 100 KVA load. Neglecting charging current and losses, draw a schematic diagram showing amplitude of all currents when secondary voltage is 2400 volts and regulator is in full boost position.

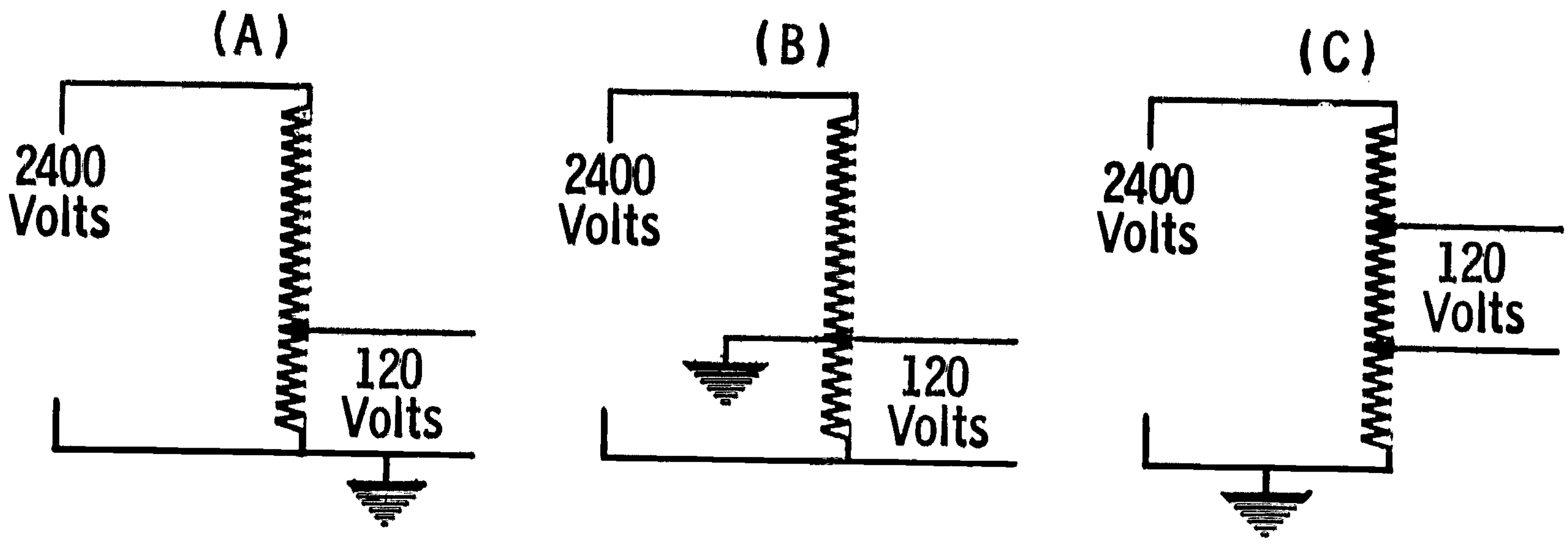


DIAGRAM FOR EXAMINATION COVERING PART IV

Sample Instruction Sheets

E 264, Electronics

Topic: The Sweep Generator

Equipment:
- Trainer, Sweep Generator
- Oscilloscope
- Power Supply
- Variac
- 20 Volt DC Source

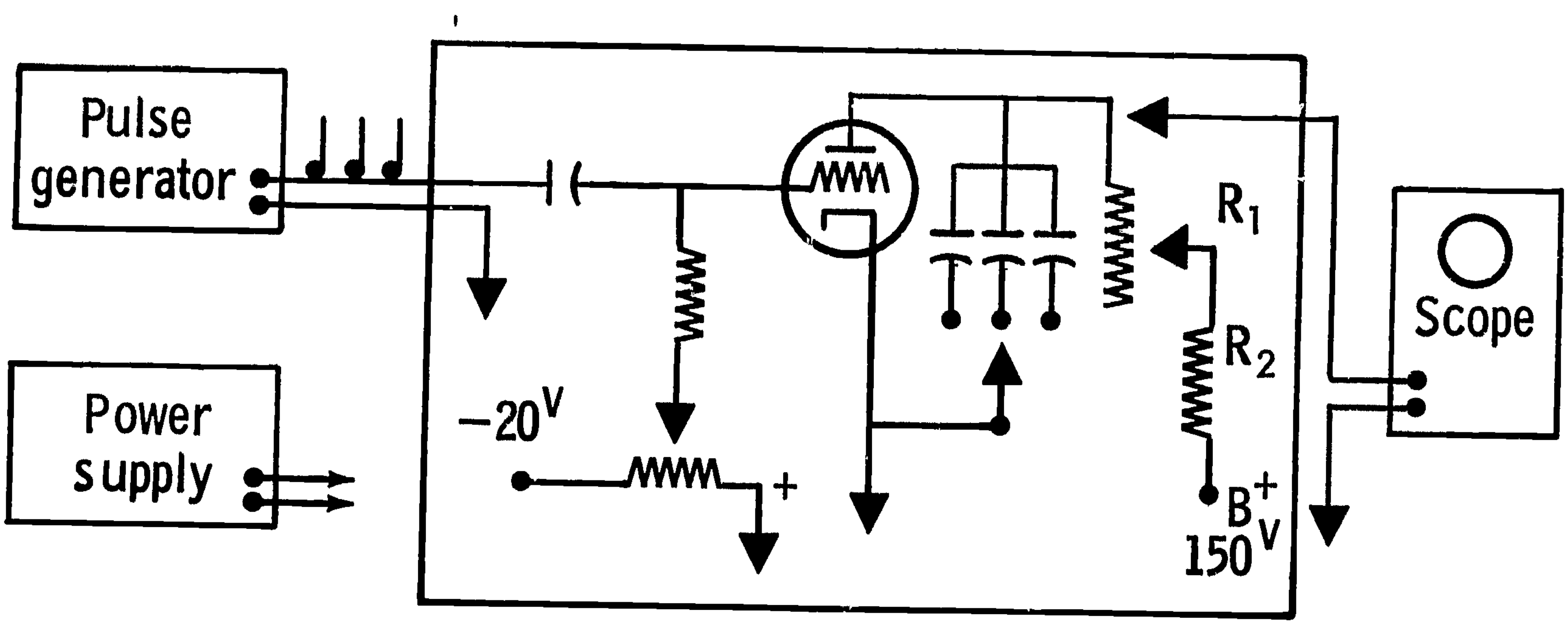
Practical Procedure:

Step 1. Connect the circuit as shown below.

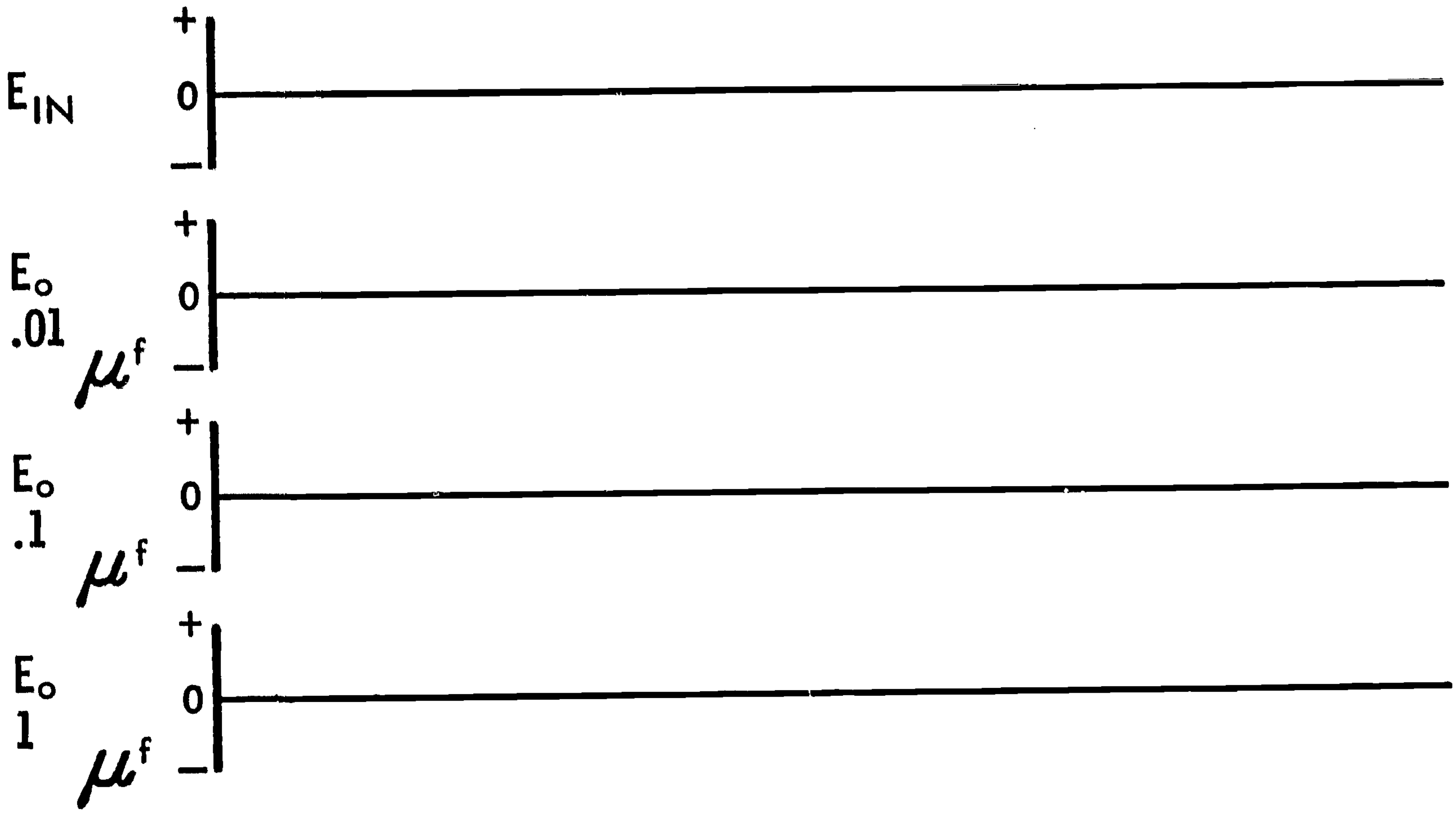
Step 2. Use the oscilloscope and record the input pulses and the output waveforms with the switch on each of the different capacitor values. (Set the bias pot on about mid-position.)

Step 3. Change the circuit values as shown in the table below and complete the chart.

Step 4. On a separate sheet of paper, explain in your own words the complete step by step operation of the sawtooth generator circuit.



SWEEP GENERATOR DIAGRAM



WAVEFORM CHART

Element Varied	Effect on Amplitude	Effect on Linearity	Effect on Duration	Wave Shape
R_1 is increased				
C is increased				
E_B is increased				
Negative bias is increased				
Amplitude of input signal is increased				

WAVEFORM CHART

E 213, Instruments and Measurements

Title: Multimeter Design and Construction

Object: To design, construct, and calibrate a multimeter with voltage and current scales.

Reference: Electronic Test Instruments by Turner.

Equipment: Meter Movement; Variable Power Supply; Necessary switches and resistors (depending on design).

Practical Procedure:

Step 1. Measure resistance of meter.

Connect the circuit as shown below, but before power is applied, be absolutely sure that the power supply is turned down to zero. With R_2 potentiometer disconnected, apply power to the circuit and bring up the voltage very slowly. Adjust the supply and potentiometer R_1 for exactly full scale deflection of the meter.

Now connect the potentiometer R_2 across the meter and adjust R_2 until the meter reads exactly half scale. Remove R_2 being careful not to disturb its setting. Measure the value of R_2 on a bridge.

Step 2. On a separate sheet of paper, design voltmeter scales of 1, 10, and 100 volts, or 3, 30, and 300 volts.

Step 3. Using this meter movement, check out from stock the values of resistances needed and connect a meter with the voltage scales calculated. See your instructor for details on constructing special resistance values.

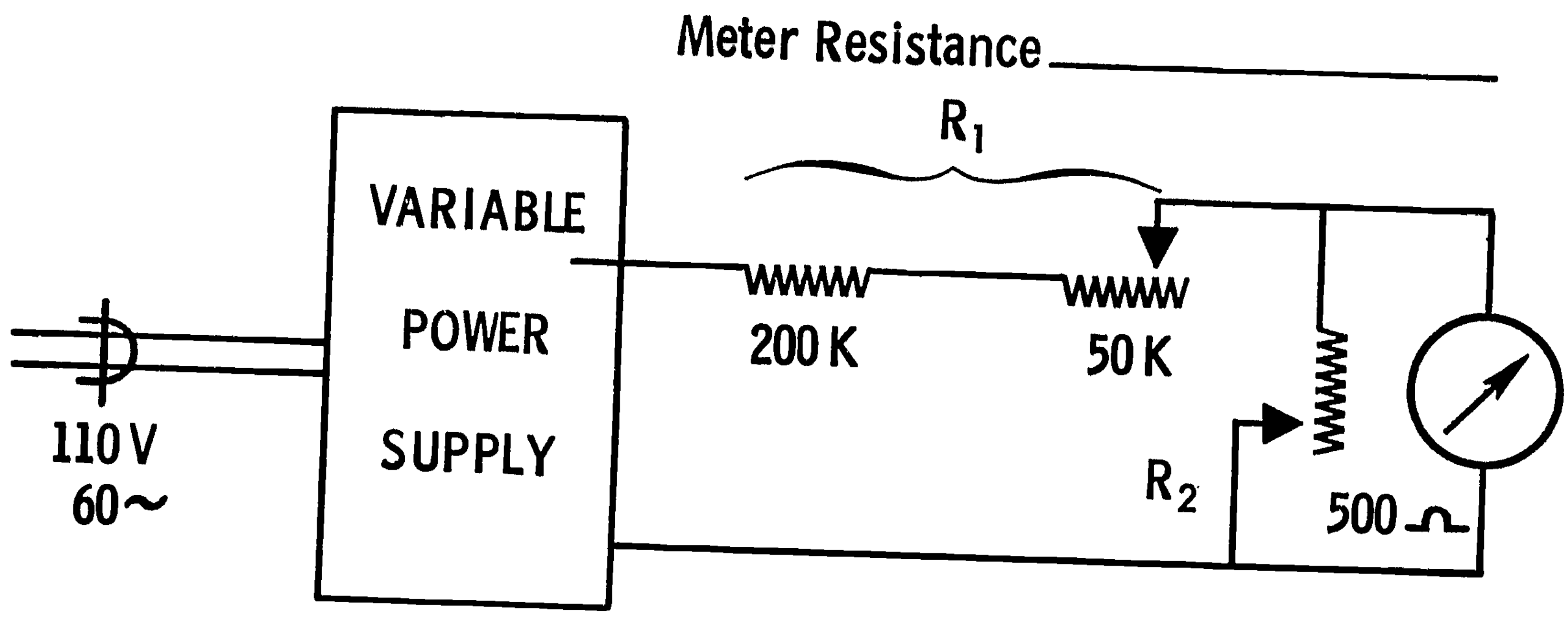
Step 4. Check the calibration of the meter scale for these voltage ranges. Plot a calibration curve. Designate multipliers to be used with the meter scale.

Step 5. Calculate the value of shunt resistance necessary for ammeter scales of 10 Ma. and 100 Ma. or 3 Ma. and 30 Ma.

Step 6. Check out from stock the values of resistance needed and construct these ranges in the meter.

Step 7. Check the calibration of the meter scale for these Ma. ranges. Plot a calibration curve. Designate multipliers to be used with the meter scale.

Step 8. Submit all calculations and drawings of finished design in report form.



CIRCUIT FOR EXPERIMENT, MULTIMETER DESIGN AND CONSTRUCTION

E 264, Electronics (Industrial)

Topic: Filter Circuits

Object: To study the frequency response of various filter circuits.

Discussion: Take notes on lecture by instructor.

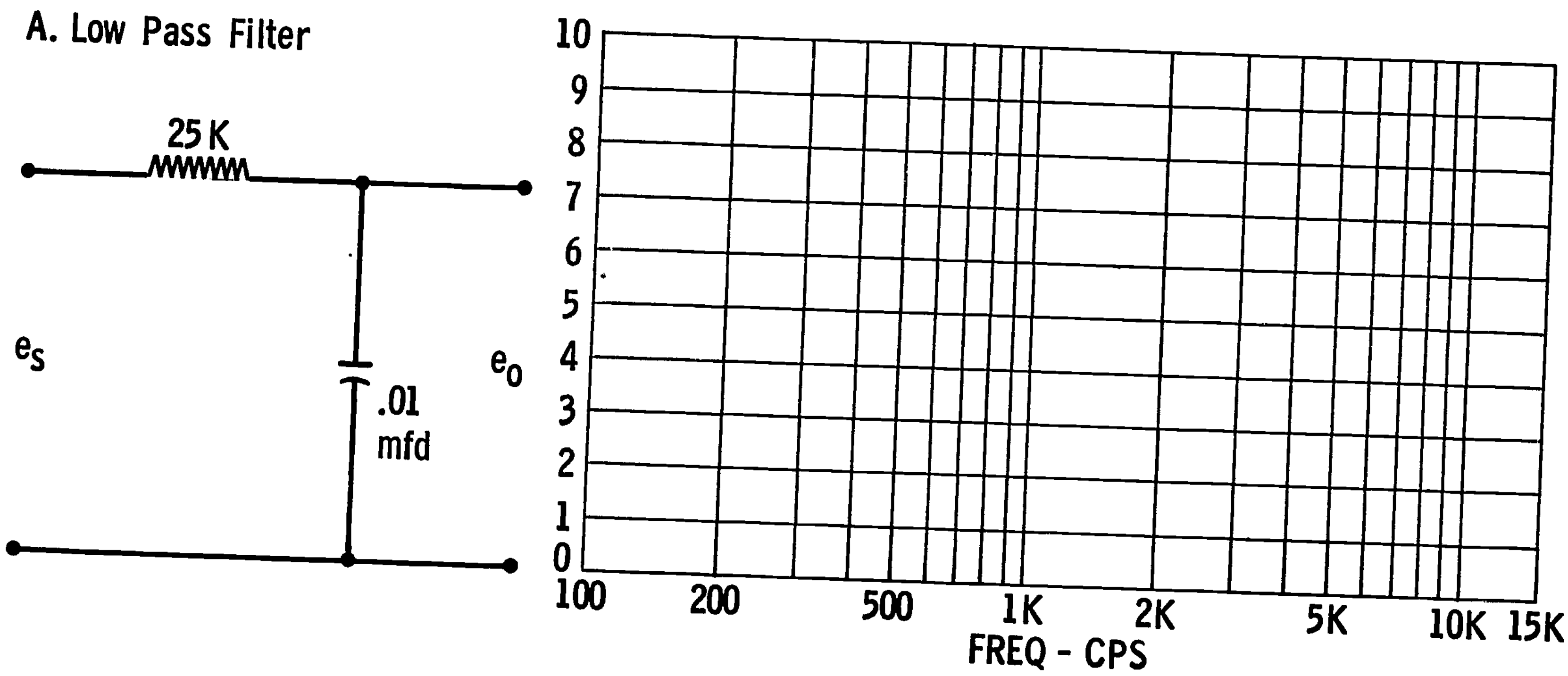
Apparatus: Connect the filter circuits as shown. To supply e_s use the audio oscillator 600-ohm terminals with a 400-ohm resistor shunted across them. Use the vacuum-tube voltmeter to measure e_o. Run through the frequency range to determine at what frequency the greatest e_o occurs. At this frequency adjust the magnitude of e_s so that e_o is 10° volts. For each of the filters sketch the curve showing how e_o varies as the frequency is varied from 100 cps to 15,000 cps.

Report: Submit the sketches of e_o vs. frequency for each filter shown. Submit answers to the questions.

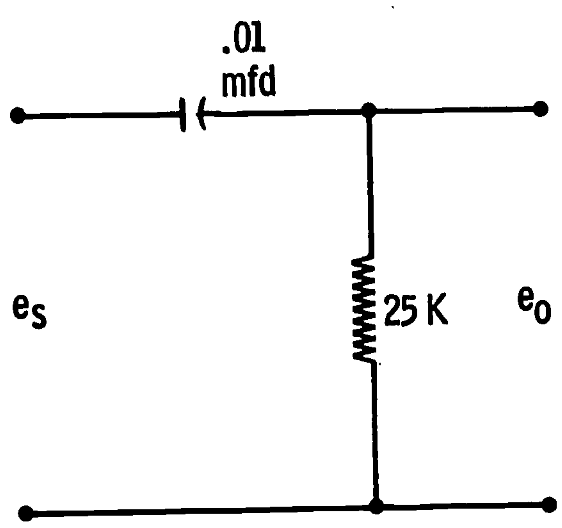
Questions:

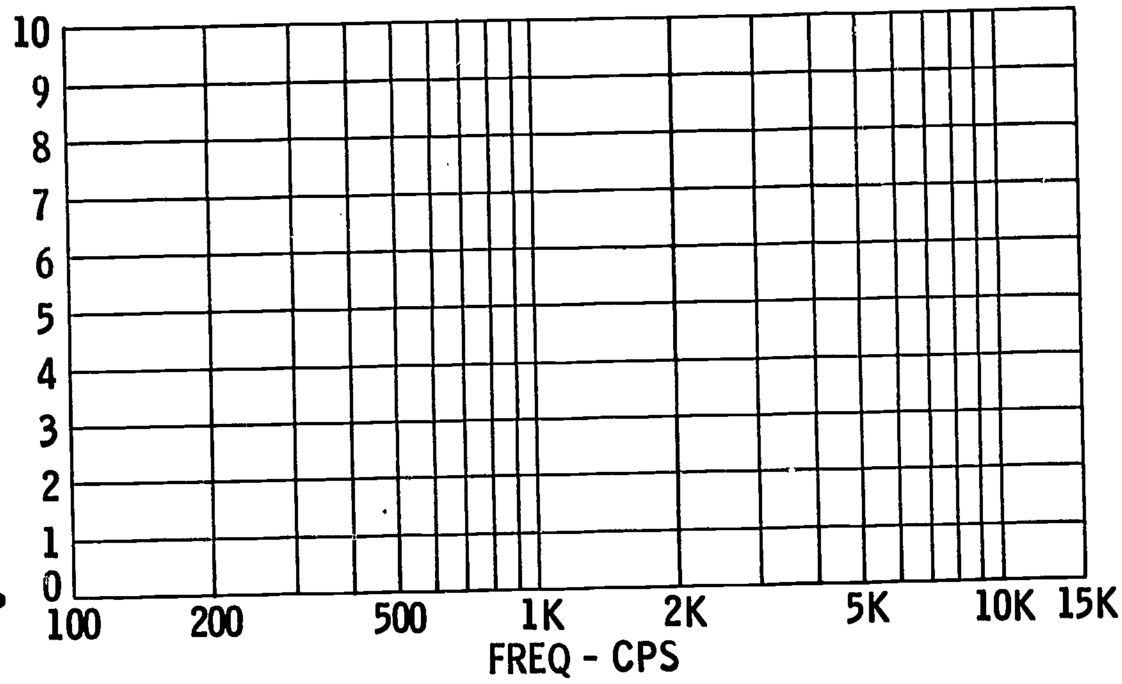
1. Indicate by diagram how you would connect coils and condensers to make a "π"-type low-pass filter.
2. Indicate by diagram how you would connect coils and condensers to make a "T"-type high-pass filter.
3. What class of filter would you use to separate an r.f. component at 3,500 kc. from an a.f. component at 5,000 cycles?
4. What class of filter would you employ to separate a zero frequency (d.c.) component from a number of a.c. components?
5. Show by a diagram how a low-pass π-type filter, with cutoff frequency of 3,000 cycles, could be combined with a high-pass π-type, with cutoff of 2,000 cycles to pass a band of frequencies approximately 1,000 cycles wide. Explain why the effect is "band-pass."
6. Show by the use of a diagram how a low-pass T-type filter and a high-pass T-type could be connected to

A. Low Pass Filter

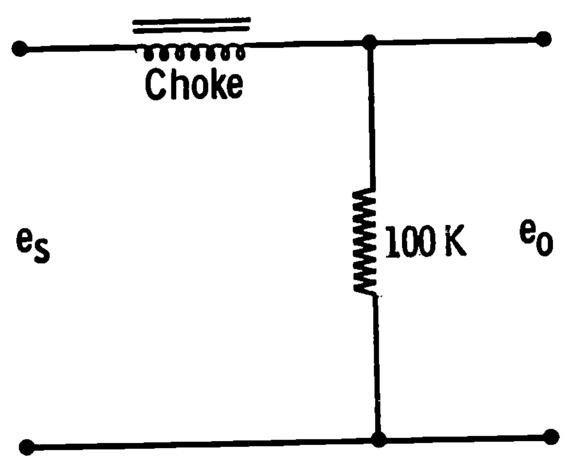


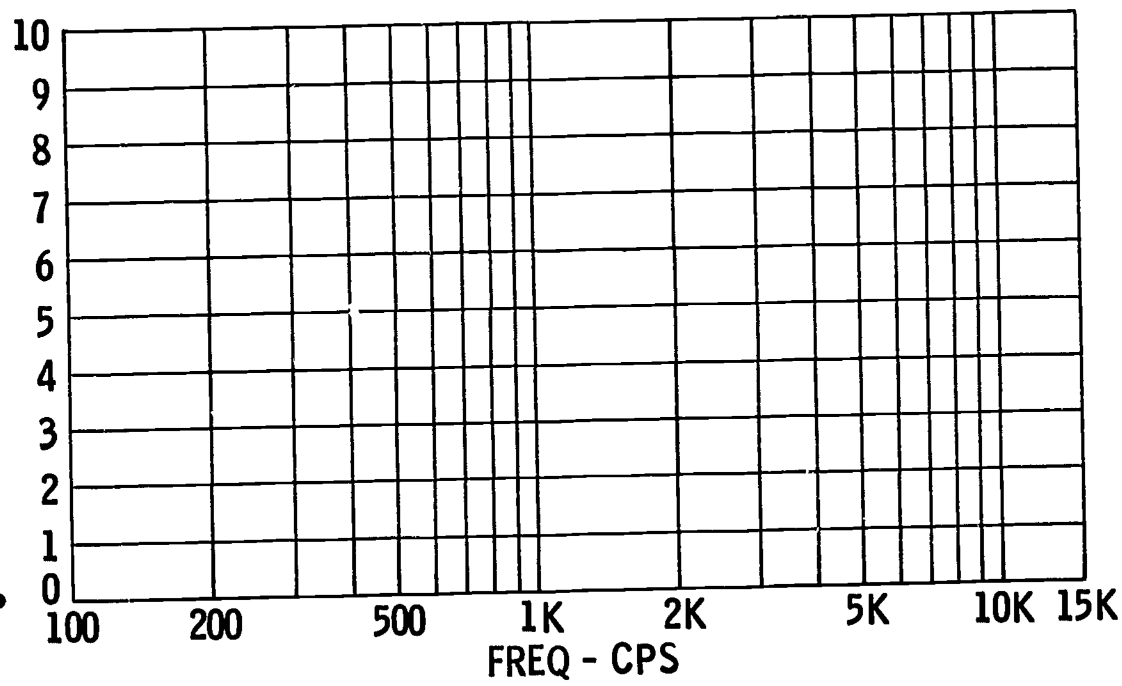
B. High Pass Filter



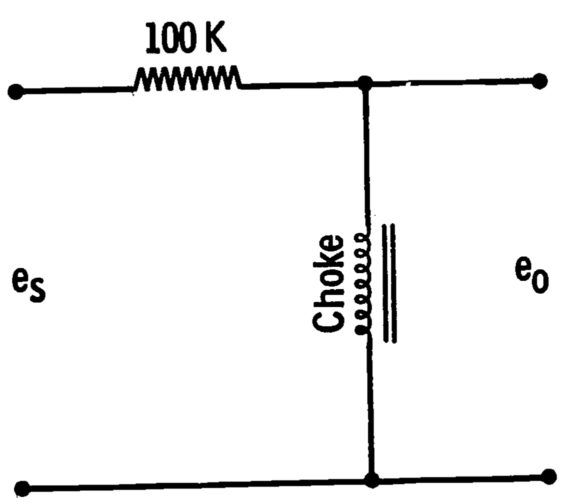


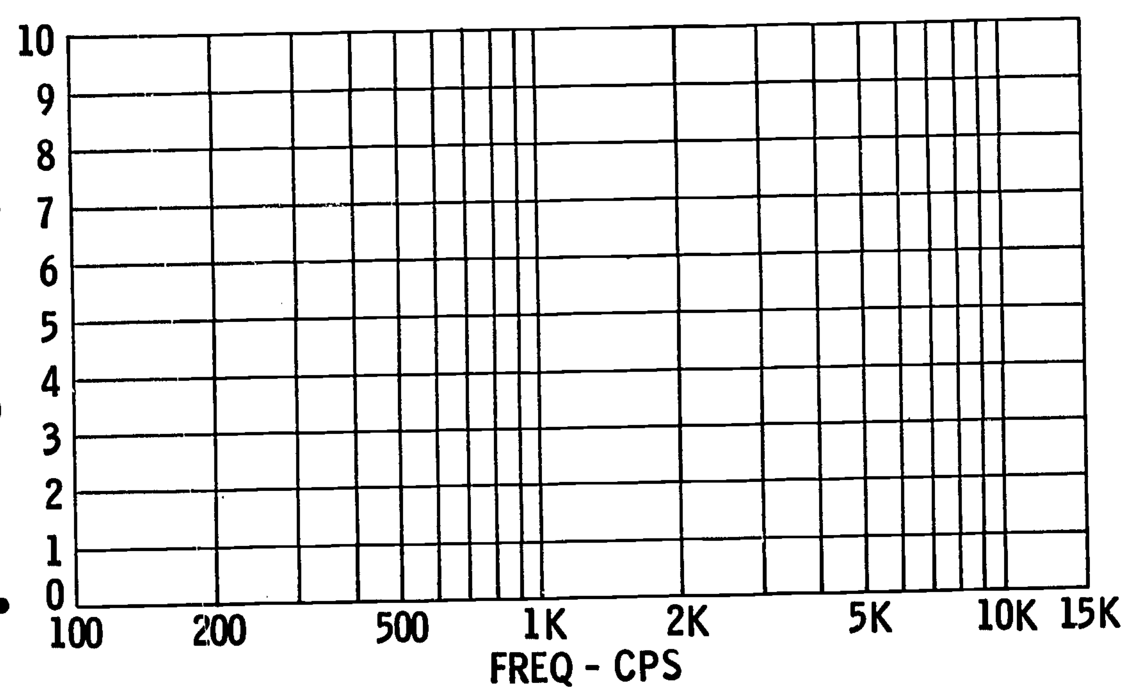
C. Low Pass Filter



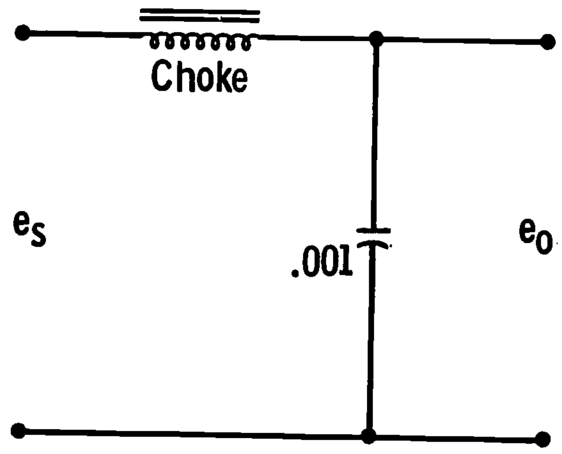


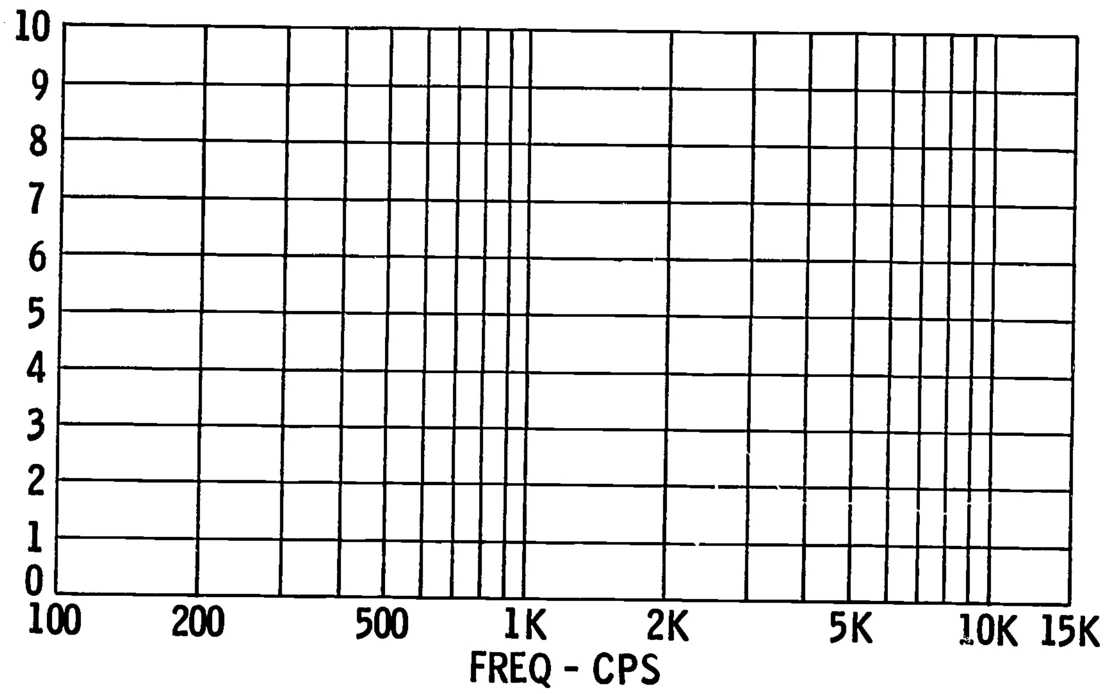
D. High Pass Filter



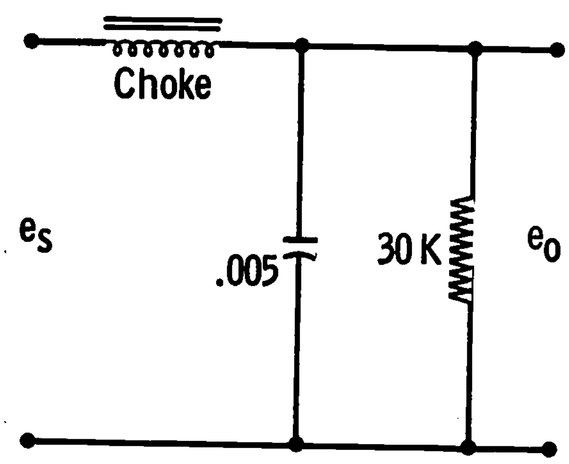


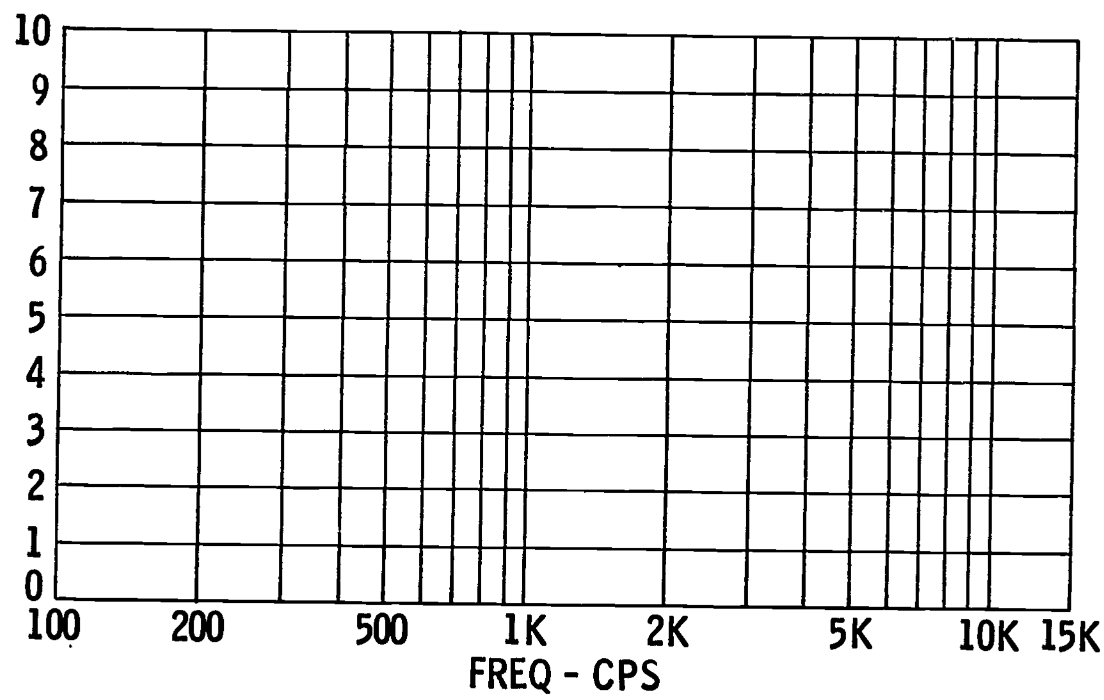
E. Band Pass Filter



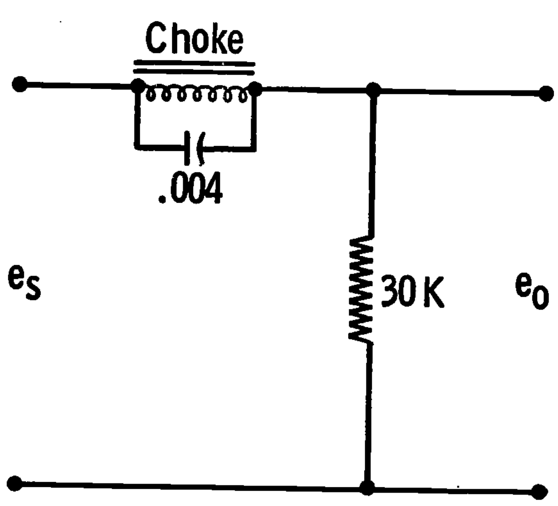


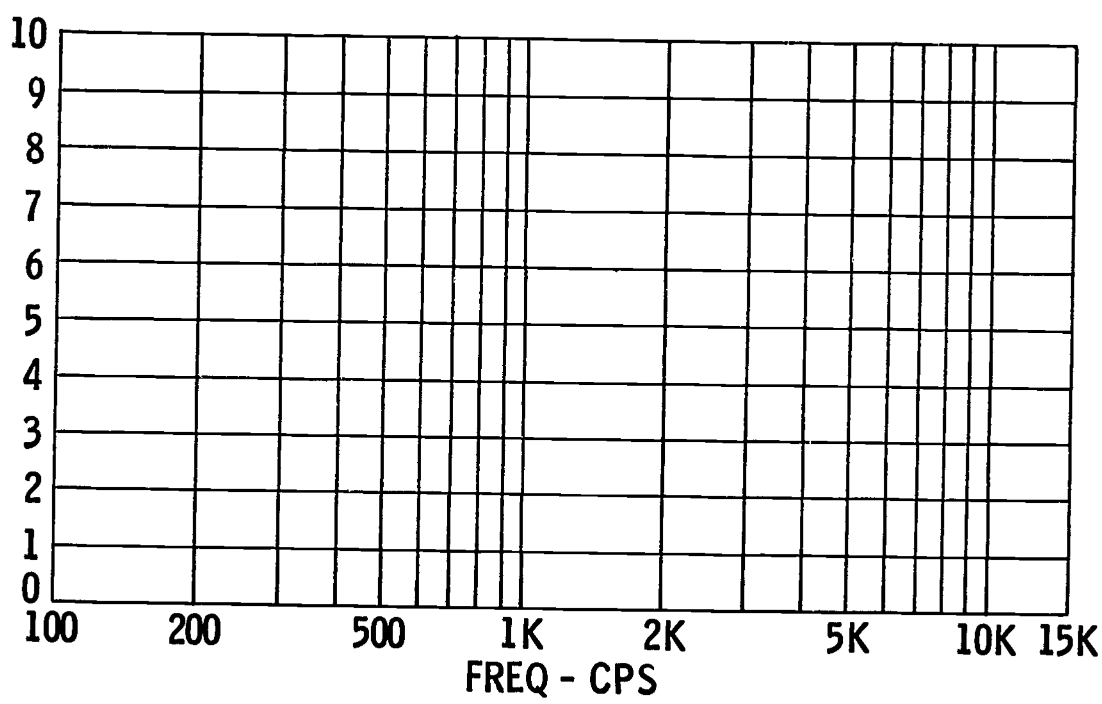
F. Low Pass IC Filter with Load



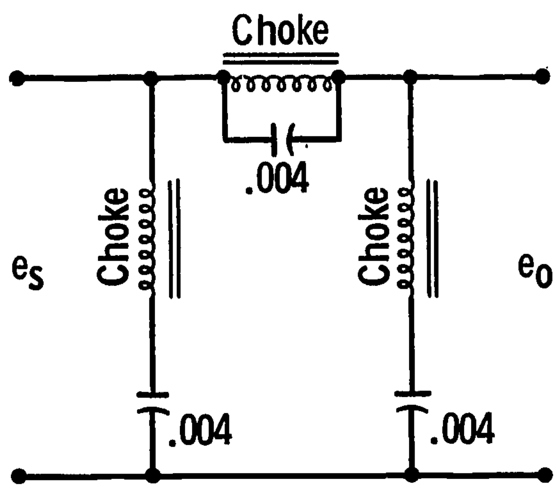


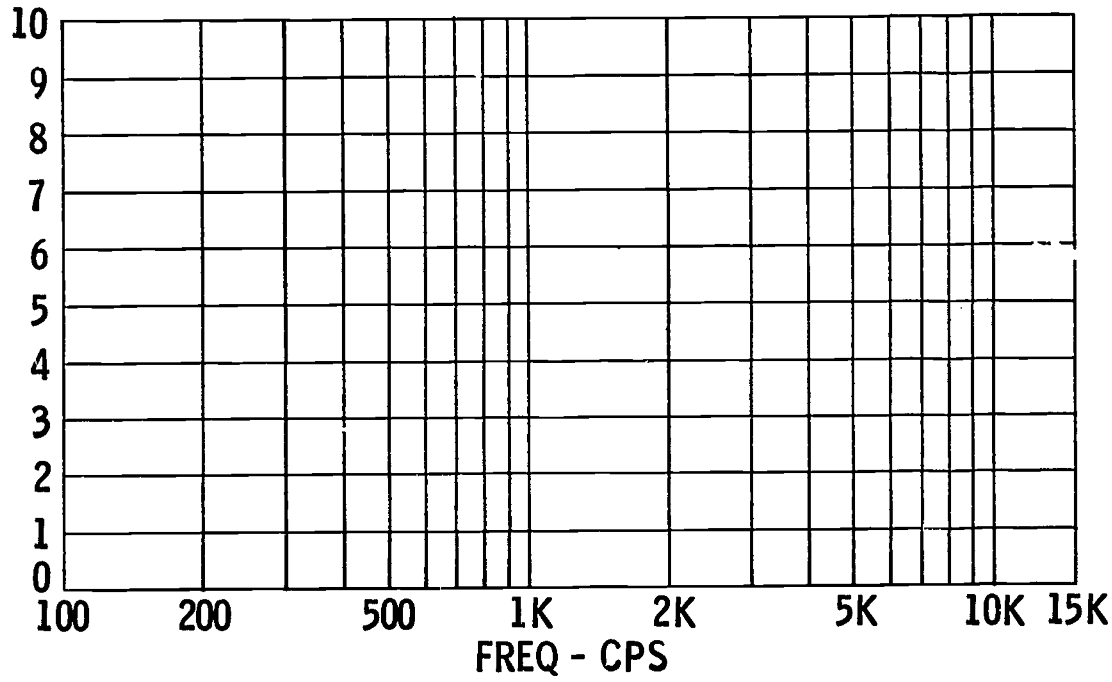
G. Band Suppression Filter



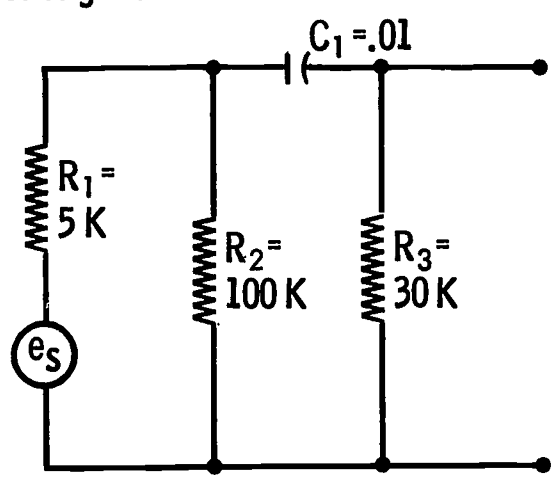


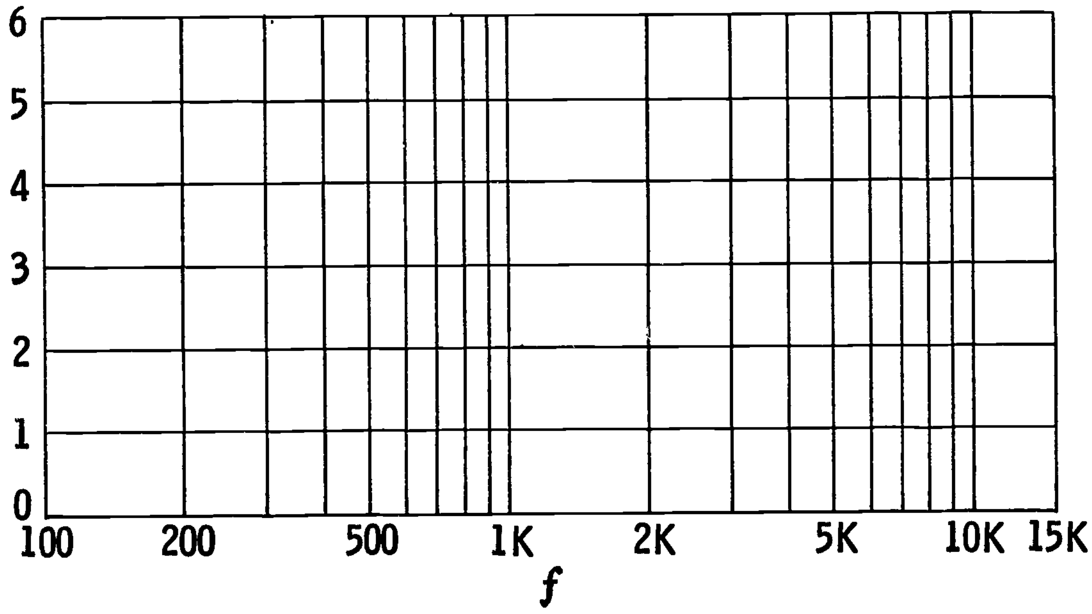
H. Band Suppression Filter
Pi Section



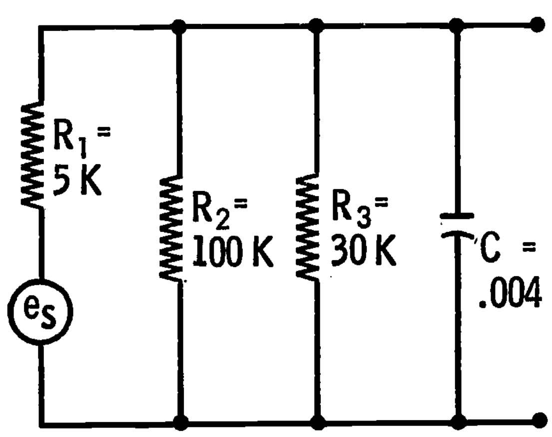


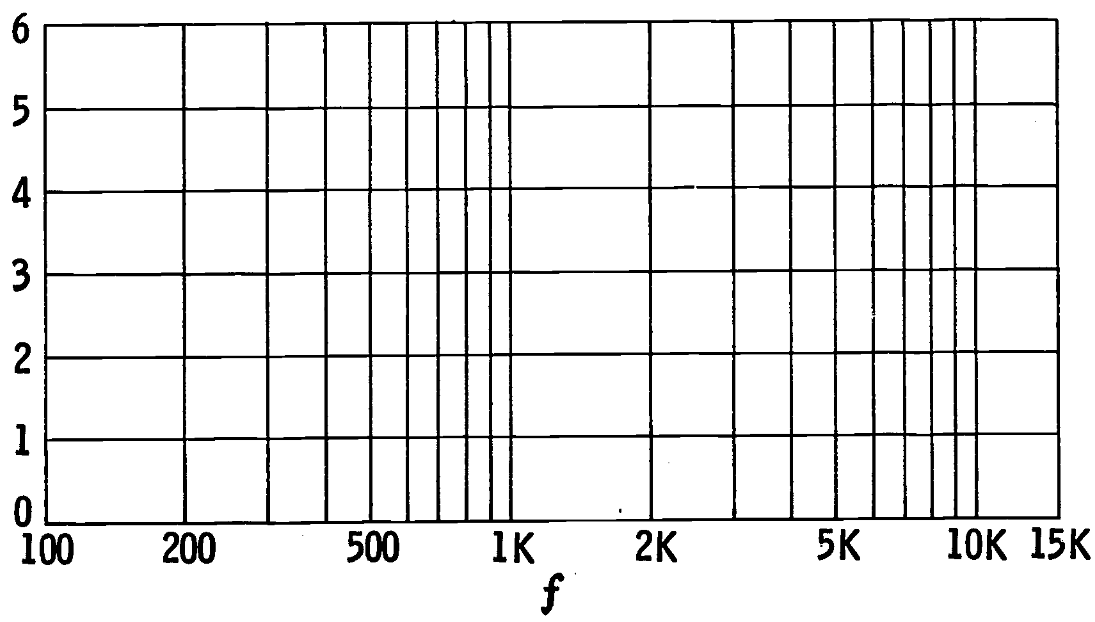
I. High Pass Filter



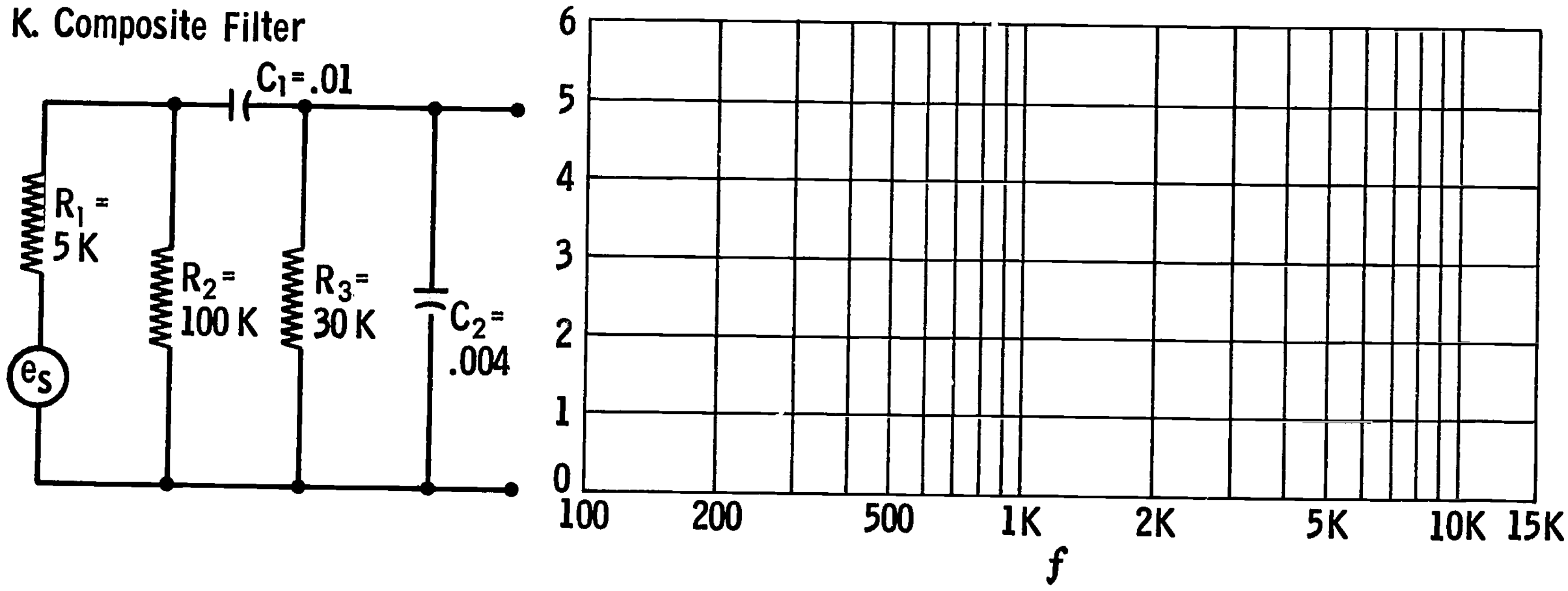


J. Low Pass Filter





K. Composite Filter



eliminate a band of frequencies from 1,500 cycles to 2,000 cycles but pass all other frequencies from 100 to 5,000 cycles. Indicate the approximate cutoff frequency of each type and explain the operation.

7. When is more than one filter section required? (Be specific.)
8. If one filter section provides an attenuation of 60-to-1 of an undesired voltage, how much attenuation will two similar filter sections provide?
9. By the use of a diagram show how you would connect resistors and condensers to separate a zero frequency (d.c.) component, a 5,000 cycle component, and a 1,000 KC component.
10. What would be the effect of reducing the resistance of the filter choke in filter "G" to a very low value?
11. Across which element in filter "K" do the very low frequencies appear?
12. Across which element in filter "k" do the very high frequencies appear?
13. If it is desired to obtain more voltage at the very low frequencies in filter "K", which element should be increased or decreased?
14. If it is desired to obtain more voltage at the very high frequencies in filter "K", which element should be increased or decreased? (Be specific.)

Suggested Standards for Laboratory Report Writing

General Characteristics

Tests of equipment are usually summarized in the form of reports. In most cases these reports are submitted to those who have not been actively engaged in the tests; hence the reports must be clear and concise enough to leave no doubt concerning the method of test and the interpretation of the results.

The report should be written in the past tense and in the third person. It should be impersonal throughout, personal pronouns being avoided. The report must be complete in itself so that it can be followed by a reader without extensive knowledge of the test under consideration. A good report is thorough, orderly, neat, and grammatically correct.

Specifications

1. Write with ink or use a typewriter.
2. Use 8½ x 11 inch paper. (Ruled paper for handwriting).
3. Write on one side of the paper only.
4. Draw all illustrations, circuit diagrams, and curves neatly and carefully.
5. Letter or type all information on drawings, circuit diagrams, and curves. Do not mix lettering styles.
6. Assemble the sheets in the order given in the following report outline. Submit the material in a standard report folder with the brads inserted through the back cover only, with the heads on the outside.

Report Outline

The material should be arranged in the following order:

I. Title Page
II. Introduction
III. Method of Investigation
  A. Procedure
  B. Circuit diagrams
IV. Results
  A. Data
    1. Nameplate data of equipment
    2. Observed and calculated data
  B. Sample calculations
  C. Curves
V. Analysis of Results
VI. Questions

(Not more than one of the above six divisions should be included on a single page. Omit Roman numerals.)

Discussion of Report Outline

I. Title Page

On this page should appear the name of the school, the course number and title, the date performed, the date submitted, the name of the student reporting, and the name of co-worker or co-workers. This page may be omitted if the form printed on the report folder includes these items.

II. Introduction

The introduction should be a concise statement setting forth the aim and scope of the investigation.

III. Method of Investigation

A. Procedure. In this section a general description of the procedure should be given. It should be comprehensive but brief. The enumeration and detailed description of routine mechanical operations and their sequence—such as closing switches, reading instruments, turning knobs, and so forth, should in general be avoided. However, when a specific method of mechanical operation is necessary to assure the validity or accuracy of the test data, it is important that the essential details be included in the description.

B. Circuit Diagrams. Each diagram should have a figure number, and should be referred to in the text material by that number. Each figure should have a descriptive title. Small diagrams may be included in the body of the description, or several may be drawn on one separate sheet if the result is not crowded. Standard symbols should be used.

IV. Results

A. Data. The first item under results should be the nameplate data—or equivalent identification—of the apparatus tested. The original observed data and the calculated data should be presented in tabular form. If the observed data require corrections, these should be made before tabulation. Instrument identification numbers and ranges need not be copies from the original laboratory data sheet.

B. Sample Calculations. This section should consist of a sample of a complete calculation of each type involved in the determination of calculated data and the solution of problems. When a succession of calculations is required in order to reach a final result, the same set of observed data should be used in carrying through the successive sample calculations, i.e., the same sample figures that are selected from a data column should be used in all calculations involving that set of data.

C. Curves. All curve sheets should conform to the following specifications:

1. Use "twenty to the inch" coordinate paper, 8½ x 11 inches for rectangular plots.
2. Plot in the first quadrant where only one quadrant is needed.
3. In general, make the axes intersect within the sectioned part of the paper. Leave the curve sheet margins blank.
4. Plot the independent variable as abscissa and the dependent variable as ordinate.
5. In general, start the scale of the dependent variable but not necessarily the scale of the independent variable, at zero.
6. Choose scales that are easy to use and that do not allow points to be plotted to a greater accuracy than that justified by the accuracy of the data.
7. Indicate points plotted from data by visible dots or very small circles.
8. Draw a smooth average curve through the plotted points except in cases in which discontinuities are known to exist. Use a French curve in drawing the curves.
9. Place a title containing all pertinent information on each curve sheet. The title should be lettered or typed. Label the axes and show the units in which they are marked.
10. Draw only related curves on the same sheet.
11. Insert curve sheets in the report so that they can be read from the bottom or right side.
12. Use ink for everything on the sheet except the curves themselves; these should be drawn with a colored pencil.

V. Analysis of Results

The analysis of results is the most important section of the report. As the name implies, it should be a complete discussion of the results obtained. Part of the discussion should deal with the accuracy or reliability of the results. It is suggested, where applicable, that this section consist of a careful treatment of the effect on the results of the following:

(1) Errors resulting from the necessity of neglecting certain factors because of physical limitations in the performance of the test, (2) errors in manipulation, (3) errors in observation, and (4) errors in instruments.

A very important part of the discussion should be a comparison of the results obtained with those which would reasonably have been expected from a consideration of the theory involved in the problem. Whenever the theory is apparently contradicted, the probable reasons should be discussed. When results are given in graphical forms as curves, the shape of each curve should be carefully explained. Such an explanation should state the causes for the particular shape the curve may have.

Any original conclusions drawn as a consequence of the laboratory procedure and a study of the results obtained should be included in this section.

VI. Questions

In this section should be included answers to any questions which are given as a part of the test.

Sample Laboratory Report

Experiment No. 4

ER 185, Time Varying Circuits

Topic: Series Resonance

References:

Dawes, Chester L., *Electrical Engineering*, Volume II
Fitch and Potter, *Theory of A. C. Circuits*
Morecock, Earle M., *Alternating Current Circuits*

Object:

To investigate the properties of a series circuit when resonance is obtained by varying the frequency of the input voltage.

Procedure:

1. Connect a resistor of 40 ohms, a coil of about 76 mh., and a capacitor of about 1 uf in series. Check the actual values of C and L on the bridge and use values such that the resonant frequency will be between 850 and 950 c.p.s.
2. Connect meters in the above circuit to read V_t, V_c, V_L, V_R, and P.
3. Beginning at 60 c.p.s., and with an impressed voltage of 50 volts, take readings of all of the items in part 2 at steps of 100 c.p.s. except for frequencies within 100 c.p.s. on either side of the resonant frequency, and within this range take readings in steps of 25 c.p.s., or less, to clearly define the peaks.

4. Triple the series resistance and repeat part 3.
5. Correct data to reading that would have been received from a constant 100-volt source.

Report:

1. Plot on curve sheet one as a function of frequency the values of V_t, V_R, V_c, and V_l, and I obtained in part 3. Indicate the resonant frequency.
2. Plot data taken in part 4 versus frequency as before. (Curve sheet 2.)
3. From bridge measurements of the circuit elements, calculate the Q and the pass bands for the two circuits in parts 3 and 4.
4. Calculate the power factor from meter readings for each step as P/VI.
5. On curve sheet 3, plot the currents in parts 3 and 4 versus frequency. Indicate on this graph the resonant frequency, the calculated pass band, and the experimental half-power points from I_m exp. $\times .707$. Also, plot on this same graph the calculated power factors from part 4 immediately above.

Questions:

1. Compare intelligently the experimental half-power points and the calculated pass band. Explain the power factor curve. Which side of resonance is leading power factor and which is lagging?
2. Explain, and verify by formulas, the relative positions of the peaks of V_c, V_L, V_R, and I.

ELECTRICAL TECHNOLOGY

THE TECHNICAL INSTITUTE

Course ER - 185

TIME VARYING CIRCUITS

Experiment No. 4

Title: The properties of a series circuit when resonance is obtained by varying the frequency of the input voltage

Name..John..Smith...

Date.4/12/60.....

Introduction:

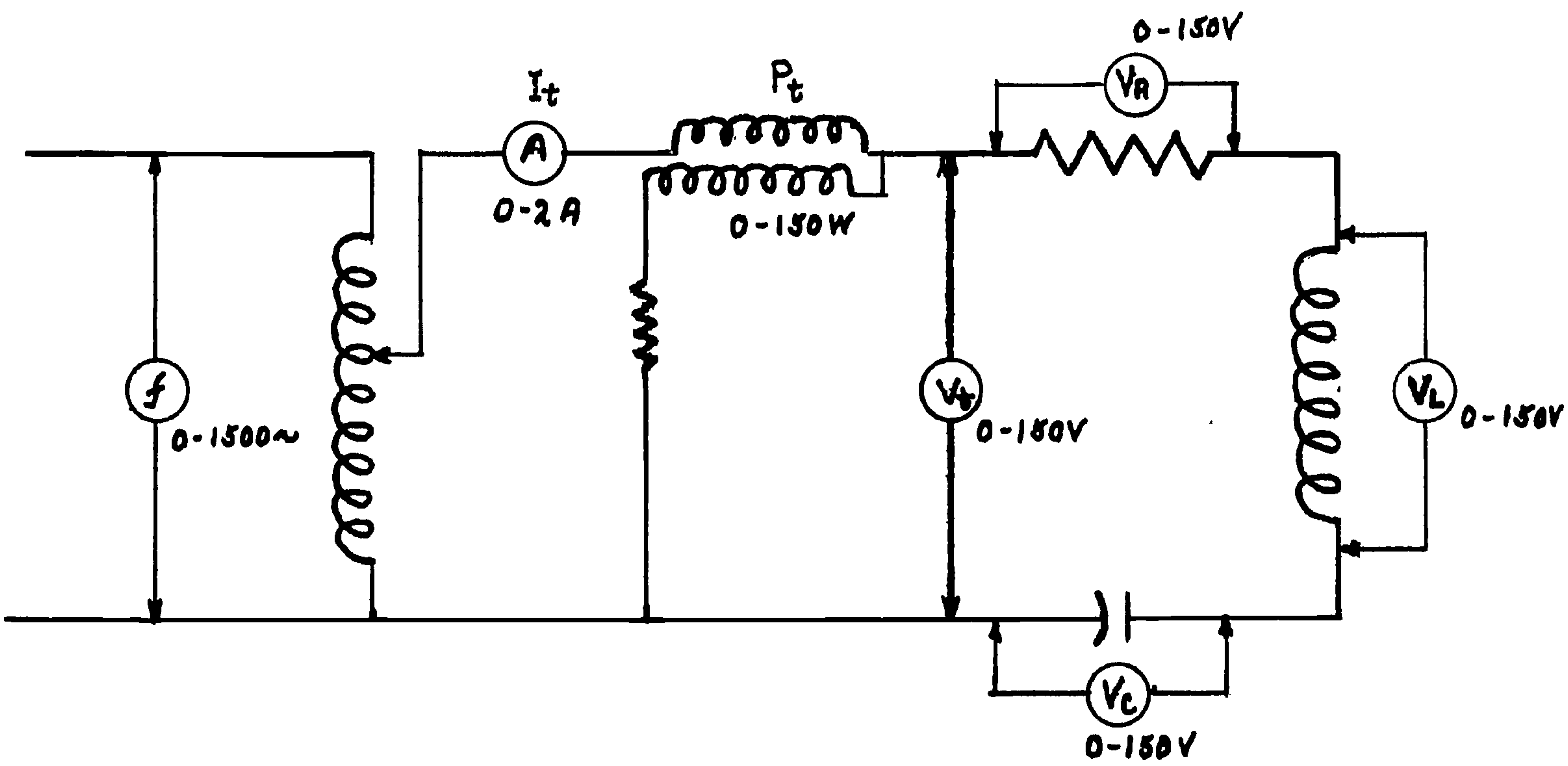
It has been shown that the inductive reactance of a circuit varies directly as the frequency and that the capacitive reactance varies inversely as the frequency. That is, the inductive reactance will increase and the capactiive reactance will decrease as the frequency is increased and vice versa.

The objective of this experiment is to show that for any value of inductance and capacitance in a circuit, there is a frequency at which the inductive reactance and the capacitive reactance are equal. This is called resonant frequency of the circuit. At the resonant frequency of a series circuit, the resistance is the only circuit component that limits the flow of current, for the net reactance of the circuit is zero. Thus the current is in phase with the applied voltage which results in a circuit power factor of 100 per cent.

Procedure:

A resistor of 40 ohms was connected in series with a coil of approximately 30 millihenrys and a capacitor of luf. The values of C and L were selected in order that resonant frequency would occur about 900 cycles per second and actual values checked on the bridge. A 0-2 ammeter, 0-150 voltmeter, 0-150 wattmeter and a frequency changer 0-1500 cycles were connected in the circuit as indicated in the diagram below. Readings of V_t, V_c, V_L, I_t, and P were taken at different frequencies ranging from 60 to 1100 cycles. This procedure was repeated with a 120 ohm resistor replacing the 40 ohm resistor in the circuit and the data corrected for a constant 100 volt source. From the data obtained, computations for the power factor, Q, and pass bands were made and curves plotted showing resonant frequency, calculated pass band and half-power points.

CIRCUIT DIAGRAM



CALCULATED AND TABULATED DATA

NO. 4. POWER FACTORS FROM METER READINGS

R 40 Ohms.

F.	P.F.	2 X P.F.
60	.0	.0
200	.0	.0
400	.075	.15
500	.11	.22
600	.173	.346
700	.252	.504
800	.38	.76
830	.43	.86
850	.48	.96
875	.48	.96
900	.475	.95
925	.438	.876
950	.41	.82
1000	.337	.674
1100	.356	.712

R 120 Ohms

F.	P.F.	2 X P.F.
60	.0	.0
200	.106	.212
300	.12	.24
400	.083	.166
500	.254	.508
600	.342	.684
700	.42	.84
800	.464	.928
825	.463	.926
850	.48	.96
875	.488	.976
900	.474	.948
950	.472	.944
1000	.464	.928
1100	.42	.84

EXPERIMENT NO.4. SERIES RESONANT CIRCUIT

data corrected to 100 VOLTS INPUT.

Should be in Caps

R 40 Ohms L. 29.5 mh. C 1.03 uf.

F.	V_t	V_c	V_L	V_R	I_t	P_w
60	100	100	0	0	.040	0
200	100	104	4.5	5	.135	0
400	100	108	10	8	.2	1.5
500	100	145	51	23	.5	5.5
600	100	177	84	33	.72	12.5
700	100	236	141.4	50	1.11	28.8
800	100	331	253	74.9	1.66	63.6
830	100	325	286	81.8	1.82	78.2
850	100	334	314	85.8	1.9	91
875	100	330	342	87.5	1.95	93.8
900	100	314	338	83.4	1.91	91
925	100	278	327	78	1.78	78
950	100	246	304	72	1.6	65.5
1000	100	187	259	57.4	1.31	44.2
1100	100	202	274	63.2	1.38	49.2

551292 O—60——7

EXPERIMENT NO. 4. SERIES RESONANT CIRCUIT

DATA CORRECTED TO 100 VOLTS INPUT.

R 120 ohms L 29.5 mh. C 1.03 uf.

F.	V_t	V_L	V_c	V_R	I_t	P_w
60	100	0	100	4.5	.039	0
200	100	4	103	17	.141	1.5
300	100	10	107.5	26	.209	2.5
400	100	22	115	37	.3	2.5
500	100	38	126	56.6	.42	10.65
600	100	59.4	134.8	73.2	.545	18.6
700	100	88	139.6	87	.653	27.5
800	100	114	135	95	.725	33.6
825	100	117	134	95	.735	34
850	100	125	130	97	.75	36
875	100	130	125	96	.74	36
900	100	132	125	97	.74	35
950	100	138	114	94	.72	34
1000	100	140	101	89	.69	32
1100	100	140	82	80	.62	26

DATA SHEET

EXP. #4 ER-185 GROUP 3

		R =	40Ω				
f	Vt	Vc	VL	VR	It	Pw	
60	100	100	0	0	40ma.	0	
200	100	104	4.5	5	135ma.	0	
400	100	108	10	8	.2	1.5	
500	96	139	49	22	.48	5	
600	100	177	84	33	.72	12.5	
700	72	170	106	36	.8	15	
800	47	144	119	35	.78	14	
830	44	143	126	36	.8	15	
850	42	140	132	36	.8	16	
875	40	132	137	35	.79	15	
900	42	132	142	35	.805	16	
925	45	125	147	35	.8	16	
950	50	123	152	36	.8	16.5	
1000	61	114	158	36	.8	16	
1100	57	115	156	36	.79	16	
f	Vt	VL	R = 120Ω Vc	VR	It	Pw	
60	102	0	102	4.6	40ma.	0	
200	100	4	103	17	.141	1.5	
300	100	10	107.5	26	.209	2.5	
400	100	22	115	37	.3	2.5	
500	92	35	116	52	.39	9	
600	101	60	136	74	.55	19	
700	101	89	140	88	.66	28	
800	102	116	138	97	.74	35	
825	100	117	134	95	.735	34	
850	100	125	130	97	.75	36	
875	100	130	125	96	.74	36	
900	100	132	125	97	.74	35	
950	100	138	114	94	.72	34	
1000	100	140	101	89	.69	32	
1100	100	140	82	80	.62	26	
		L =	29.5mh.	C =	1.03μfd.		

Sample Calculations

(Correcting to 100 Volts Input)

Let $\underline{R}$ = Exp Readings
And $\underline{C}$ = Corrected Data

Set the Slide Rule To Read

$$\frac{V_{\underline{R}}}{V_{\underline{C}}} = \frac{V_{C\,R}}{V_{C\,\underline{C}}} \quad \frac{V_{L\,R}}{V_{L\,\underline{C}}} \quad \frac{V_{R\,\underline{R}}}{V_{R\,\underline{C}}} \quad \frac{I+\underline{R}}{I+\underline{R}}$$

Corrections For 700 Cycles Readings

$$\frac{72}{100} = \frac{170}{\underline{\underline{236}}} = \frac{106}{\underline{\underline{141.4}}} = \frac{36}{\underline{\underline{50}}} = \frac{.8}{\underline{\underline{1.11}}}$$

$$\frac{V_{\underline{R}}^2}{V_{\underline{C}}^2} = \frac{P_{\underline{R}}}{P_{\underline{C}}} \quad \frac{72^2}{100^2} = \frac{5200}{10000} \quad \frac{15}{\underline{\underline{28.8}}}$$

Finding Power Factor

For 700 cycles

$$P.F. = \frac{P}{VI} = \frac{28.8}{(100)(1.11)} = .252$$

This P.F. was ½ what it should have been So

$$P.F = .252 \times 2 = \underline{\underline{.504}}$$

No. 5. Experimental Half-Power Points

For the 40Ω Circuit

$I_{m_{Exp.}} = 1.95\ A.$

$\text{Half-Power Point} = I_{m_{Exp.}} \times .707$

$= \underline{\underline{1.38\ A.}}$

For the 120Ω Circuit

$I_{m_{exp.}} = .75\ A$

$\text{Half Power Point} = I_{m_{exp.}} \times .707$

$= .75 \times .707$

$= \underline{\underline{.53\ A}}$

No. 5. Calculated and Experimental Pass Bands

For 40 Ω Circuit

$$f_{m\,Exp.} = 865\sim$$

$$\tfrac{1}{2}\Delta w = 106 \text{ cycles}$$

$$w_1 = 865 - 106$$

$$= \underline{\underline{759}} \text{ Cycles}$$

$$w_2 = 865 + 106$$

$$= \underline{\underline{971}} \text{ Cycles}$$

For 120 Ω Circuit

$$f_{m\,Exp.} = 865\sim$$

$$\tfrac{1}{2}\Delta w = 324\sim$$

$$w_1 = 865 - 324$$

$$= \underline{\underline{541}}\sim$$

$$w_2 = 865 + 324$$

$$= \underline{\underline{1189}}\sim$$

No. 3. Calculations for Q and Pass Bands

Pass Band For 40Ω Circuit

$$\omega_m = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{(.0295)(1.03)10^6}}$$

$$= \frac{10^4}{\pm 1.74}$$

$$= 5740 \text{ Rad. Per Sec.}$$

$$f_m = \underline{\underline{914}} \text{ Cycles Per Sec.}$$

$$W_1 = W_m - \frac{R}{2L}$$

$$= 5740 - \frac{40}{.059}$$

$$= 5740 - 678$$

$$= 5062 \text{ Rad. Per Sec.}$$

$$= \underline{\underline{808}} \text{ Cycles Per Sec.}$$

$$\omega_2 = \omega_m + \frac{R}{2L}$$

$$= 5740 + 678$$

$$= 6418 \text{ Rad. Per Sec.}$$

$$= 1020 \text{ Cycles Per Sec.}$$

To Check

$$\Delta\omega = \omega_2 - \omega = \frac{R}{L}$$

$$= 6418 - 5062 = 1356 = \frac{40}{.025} = 212 \text{ Cycles}$$

No. 3. Calculations for Q and Pass Bands

Q of Series circuit When

$R = 40\,\Omega \quad L = 29.5\,mh \quad C = 1.03\,\mu f$

$Q = \frac{1}{R_S}\sqrt{\frac{L}{C}}$

$= \frac{10^2}{40}\sqrt{\frac{2.95}{1.03}}$

$= \frac{10^2}{40}\sqrt{2.86}$

$= \frac{169}{40}$

$= \underline{\underline{42.3}}$

Q of Series Circuit When

$R = 120\,\Omega \quad L = 29.5\,mh \quad C = 1.03\,\mu f$

$Q = \frac{1}{R_S}\sqrt{\frac{L}{C}}$

$= \frac{1}{20}\sqrt{\frac{.0295}{1.03 \times 10^{-6}}}$

$= \frac{10^2}{120}\sqrt{2.86}$

$= \frac{169}{120}$

$= \underline{\underline{1.41}}$

No. 3. Calculations for Q and Pass Bands

Pass Band For 120 Ω Circuit.

$$\omega_m = \frac{1}{\sqrt{LC}}$$

$$\omega_m = \frac{1}{\sqrt{(.0295)(1.03)10^{-6}}}$$

$$= \frac{10^4}{\sqrt{3.04}}$$

$= \pm 5740$ Rad. Per Sec.

$f_m = 914$ Cycles Per. Sec.

$$\omega_1 = \omega_m - \frac{R}{2L}$$

$$= 5740 - \frac{120}{2(.0295)}$$

$= 5740 - 2030$

$= 3710$ Rad. Per Sec.

$= \underline{\underline{590}}$ Cycles Per Sec.

$$\omega_2 = \omega_m + \frac{R}{2L}$$

$= 2740 + 2030$

$= 7770$ Rad. Per. Sec

$= \underline{\underline{1238}}$ Cycles Per Sec.

To check

$\Delta w = w_2 - w_1 = \frac{R}{L} = 7770 - 3710 = 4060$ Rad $= 648$ Cycles

No. 5. Experimental Half-Power Points

For 40-Ω Circuit.

$f_{m_{EXP.}} = 865\sim$

$\frac{1}{2}\Delta\omega = 106$ cycles

$\omega_1 = 865 - 106$

$= \underline{\underline{759}}$ cycles

$\omega_2 = 865 + 106$

$= \underline{\underline{971}}$ cycles

For 120-Ω Circuit.

$f_{m_{Exp.}} = 865\sim$

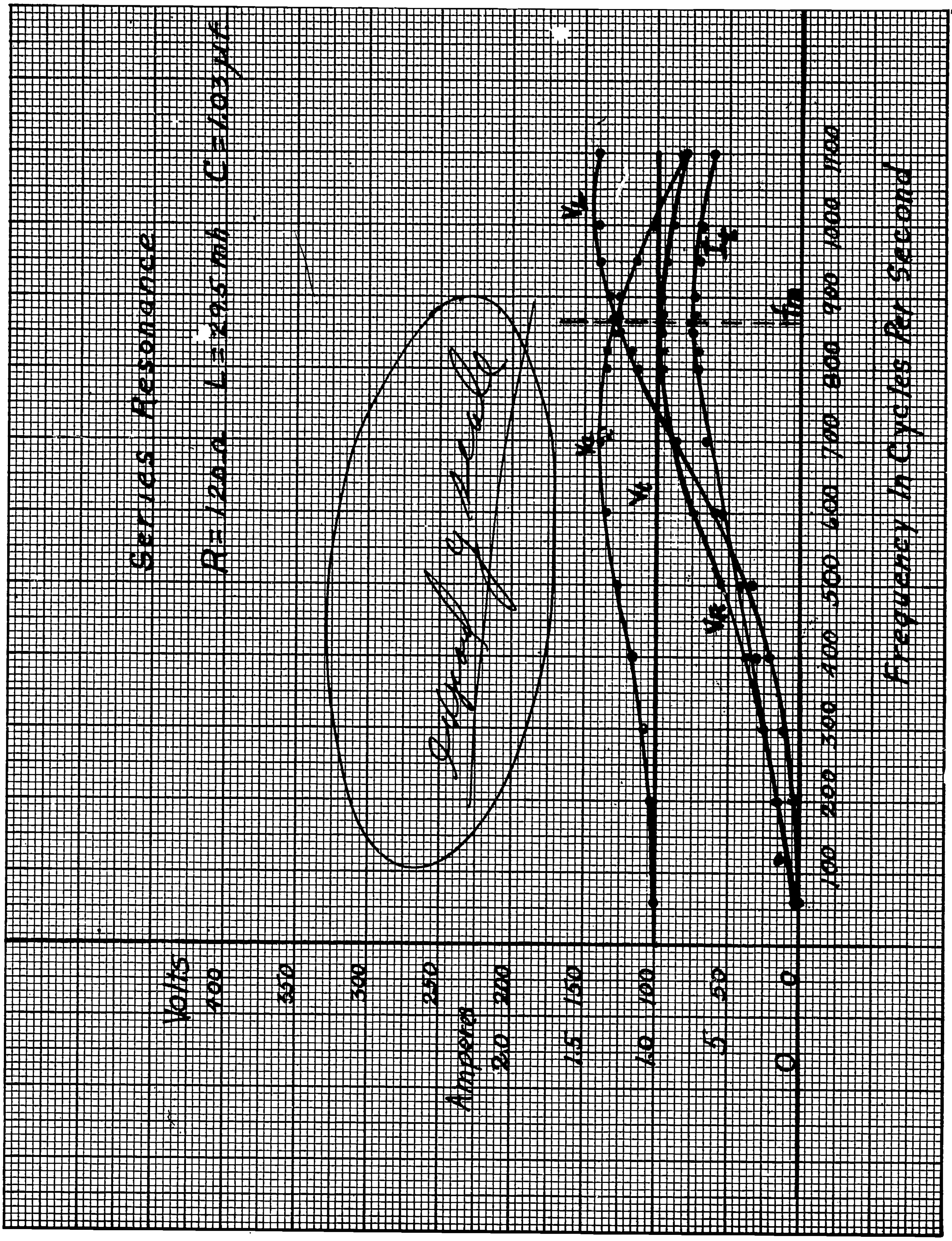
$\frac{1}{2}\Delta\omega = 324\sim$

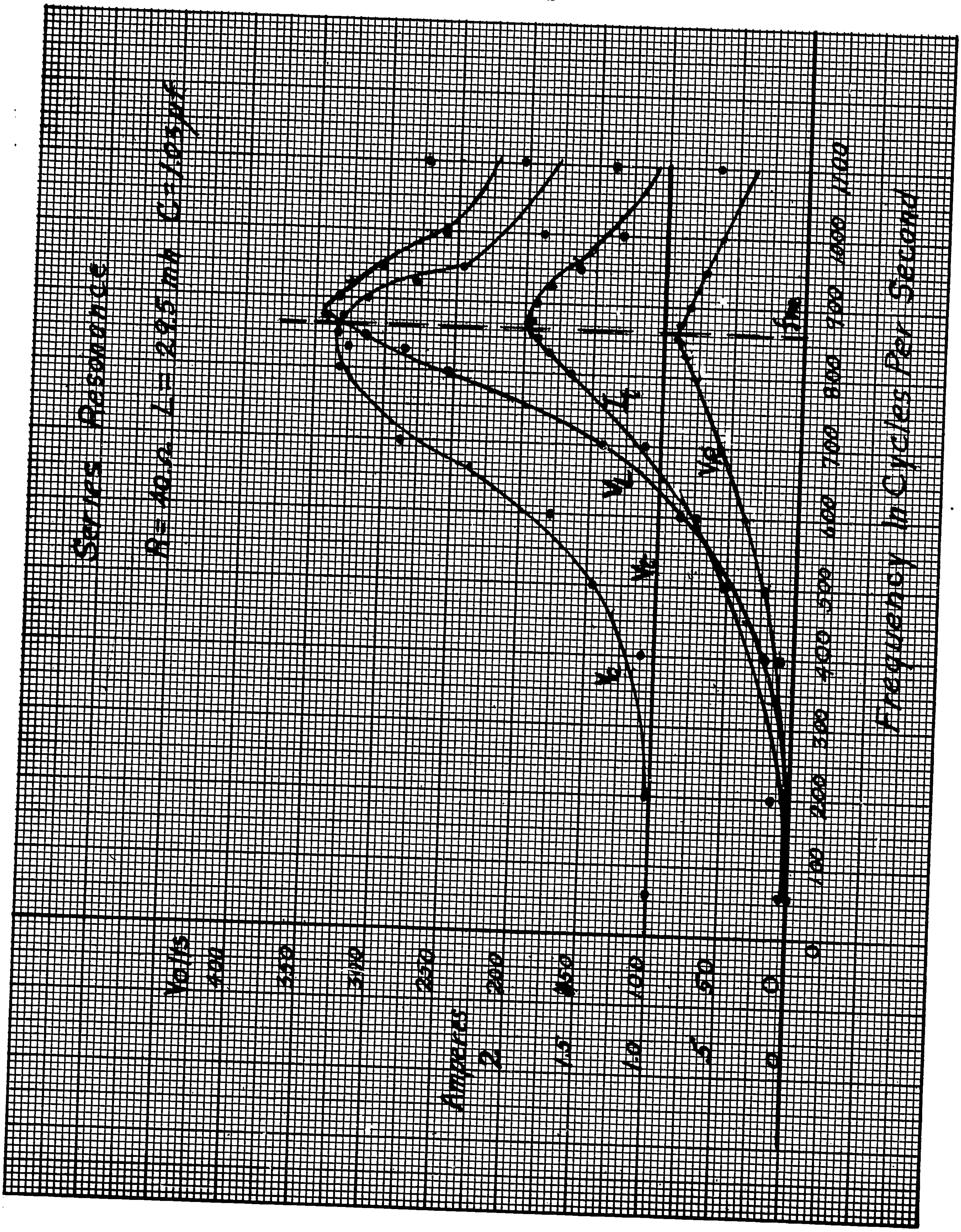
$\omega_1 = 865 - 324$

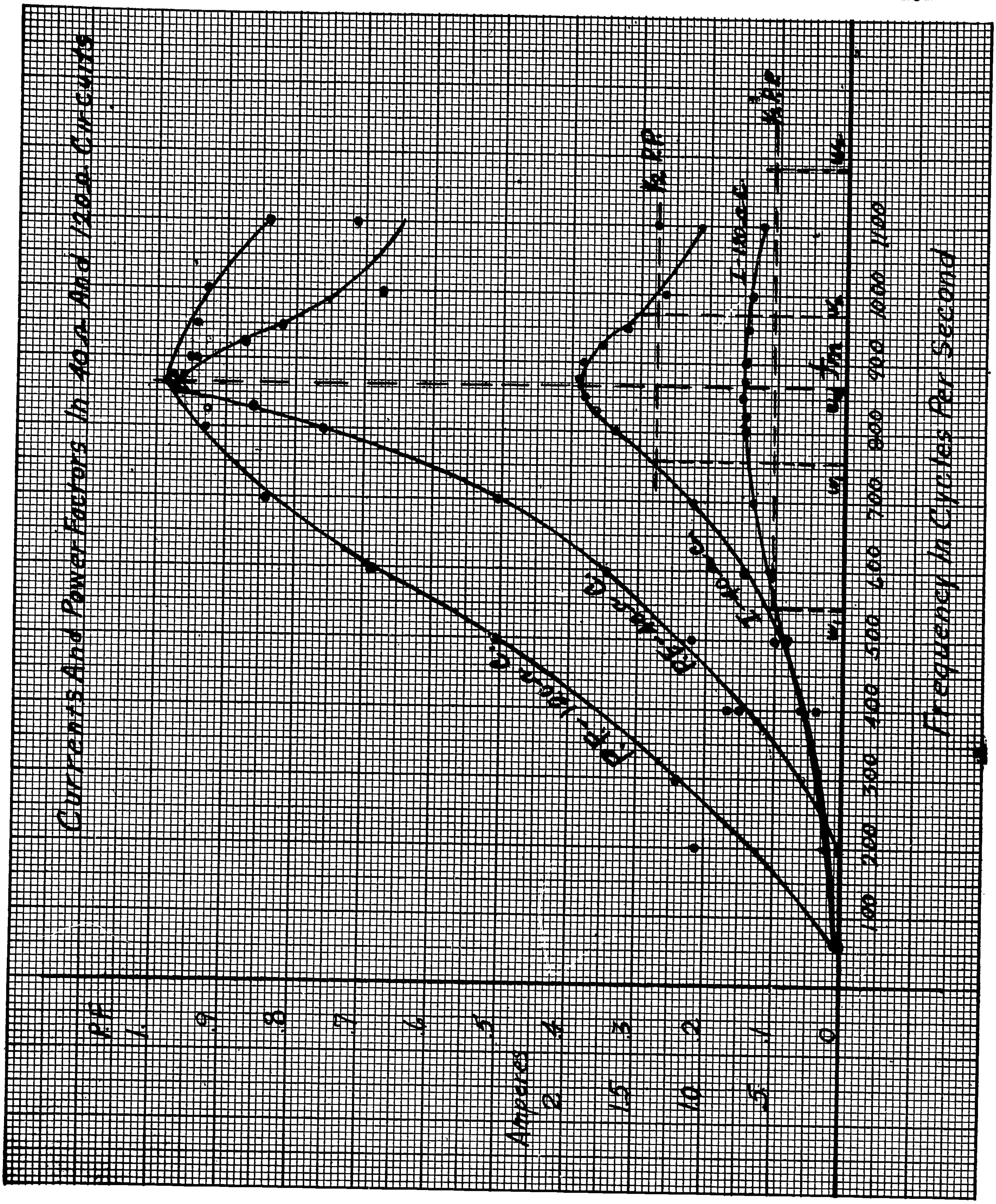
$= \underline{\underline{541}}\sim$

$\omega_2 = 865 + 324$

$= \underline{\underline{1189}}\sim$


Series Resonance
R=120Ω L=295 mh C=1.03μf
Volts
400
350
300
250
200
150
100
50
0
Amperes
2.0
1.5
1.0
.5
0
100 200 300 400 500 600 700 800 900 1000 1100
Frequency In Cycles Per Second
V_L
V_C
V_R
I_T
f_m


Series Resonance
R = 40 Ω L = 29.5 mh C = 1.05 μf
Frequency In Cycles Per Second
Volts
Amperes
I
V_L
V_C
V_R
f_m


Currents And Power Factors In 40 Ω And 1200 Ω Circuits
Frequency In Cycles Per Second
100 200 300 400 500 600 700 800 900 1000 1100
P.F.
1. .9 .8 .7 .6 .5 .4 .3 .2 .1 0
Amperes
2 1.5 1.0 .5

NO. 6. COMPARING THE EXPERIMENTAL HALF-POWER POINTS AND CALCULATED PASS BANDS

A series circuit allows more current to flow as the input voltage nears the resonant frequency. Thus over a range of frequencies near resonance it allows more current or si~~n~~gnal to pass them at the outer frequencies. This pass band has been chosen between the points on the current curve where I is greater than $\frac{V}{\sqrt{2}R}$. Since in this range the power is equal to or greater than $\frac{V^2}{2R}$ or $\frac{I^2R}{2}$, these are known as half-power points. These points are commonly found by multiplying the I_m by .707. Since the greatest power is passed at resonance which is $\omega_m = \frac{1}{\sqrt{LC}}$ the width of the pass band in cycles may be found and located. Use the formula $\omega_1 = \omega_m - \frac{R}{2L}$ and $\omega_2 = \omega_m + \frac{R}{2L}$ and change the results in radians to frequency in cycles.

THE POWER FACTOR CURVE

As the frequency of a series circuit nears the resont frequency the X_L approaches X_c and as they are 180° out of phase they tend to cancel each other out. Then as the reactance of the circuit is less the power factor approaches unity. A circuit with little resistance will have a low power factor at the lower and higher frequencies and a sharp rise toward unity ~~in the~~ power factor near resonant frequency. A circuit with greater resistance will have a higher power factor at the lower and higher frequencies and will approach unity more gradually thus producing a broader curve near resonant frequency.

NO. 6. LEADING AND LAGGING POWER FACTOR

Since in series circuits the X_c is greater at the lower frequencies and the X_L is greater at the higher frequencies the power factor is leading on the lower frequency side of resonance and is lagging on the higher frequency side of resonance.

No. 7. EXPLAINING AND VERIFYING PEAKS

The peak in the current curve is at the resonant frequency because X_L cancels X_c of the circuit leaving $I=V/R$ which allows the greatest current to flow.

V_R peaks at resonance as the greatest current is flowing at that time and the voltage drop accross R is $V=IR$ and since R is constant V_R would be greatest when I is greatest.

V_c would peak just before resonance as at resonance the current is not changing and X_c is decreasing so $V_c = IX_c$ must have ✓ been greater just before resonance.

X_L reaches its peak just after resonance as I is at its peak and not changing at resonance and X_L is increasing so $V_L = IX_L$ must ✓ reach its peak after resonance.

How can an equality be greater.

ANALYSIS OF REPORT AND CONCLUSIONS

In a series circuit the V_c and V_L are equal at the same time the I_t, P.F., and V_R reach their peaks, which is the resonant frequency of the circuit. From about 200 cycles to the top reading of 1100 cycles the voltage drop across the capacitor was greater than the applied voltage in the 40 ohm circuit. The V_L, V_R, P.F. and I_t began at or near zero at 60 cycles on the 40 ohm circuit with a gradual rise until near the resonant frequency wher e they took a sharp rise to the peak then dropped off quickly. Sp The X_c began at 60 cycles on or near the applied voltage showing that at that low frequency it was practically an open circuit.

The 120 ohm circuit had the same resonant frequency as the 40 ohm circuit which was correct as the resistance in a series circuit has only the effect of flattening out the courves when Sp the ressistance is high or allowing them to peak sharply when the resistances are small compared to the X_L and X_c of the circuit. The curves were much flatter in the 120 ohm circuit than in the 40 ohm circuit and their peaks were much lower in all cases except the P.F. which was slightly higher than in the 40 ohm circuit. The power factor is both cases should have been unity at the peaks. Why wasn't it?

The Q of the low ohm circuit was much greater than the Q of the high ohm branch.

ANALYSIS OF REPORT AND CONCLUSION

The half-power points and pass band limits coincided close enough on the low frequency side of resonance but as the data was not as accurate or complete on the high frequency side they did not mathe as well. The half-power points were higher in the 40 ohm circuit, 1.38 A. as compared to .53 A. in the 120 ohm circuit. The pass band was narrower in the 40 ohm circuit too, 212 cycles to 648 cycles for the 120 ohm circuit. The half-power points in the 40 ohm circuit were 1.38 A. when calculated by the formula I_m Exp. X .707 and 1.769 A when calculated by the formula $\frac{V}{\sqrt{2R}}$ which indicates our current readings were a little low.

✓ Sp
✓ Sp
✓ (–)
✓ (–)

Report should be impersonal

The resonant frequency as found on the curves was 865 cycles and 914 cycles as calculated. Could the capacity in (of) the coil not being considered in the calculations and being present in the coil experiment have caused this difference? Either the L or C one. should have been a little larger or our meters failed again.

✓ of
✓
impersonal!

The wattmeter readings were one half as high as they should have been so I concluded the readings were taken from a scale for twice the voltage that was used.

impersonal!

Rewrite and Correct!

Should this have been noticed when the readings were taken??

APPENDIX B—Physical Facilities Layouts

The facilities for instruction should include one area for fixed machines with the control equipment, switching circuits and instrumentation required for the equipment. This is designated as an electric power laboratory and is used primarily for demonstration and experiments. A second area is needed to accommodate the study of basic direct current and alternating current circuit behavior. If repair and maintenance function are to be studied a third area should be provided for this. It is strongly recommended that this be a distinctly separate activity auxiliary to and not a major part of the training program in technology.

Electrical Power Laboratory

This laboratory contains the basic equipment and switching circuits for the course work in E 215. It should be recognized that this represents a minimum of equipment and space rather than optimum facilities. The table and seating arrangement provide both a laboratory and lecture area—an additional space saving feature.

The circuits from the laboratory tables terminate on the distribution panel making it possible to supply power from any of the several machines to each work station on the tables. The conduit from the distribution switchboard and starting panels to the machine area should be sized to permit the installation of additional equipment as it is added.

Power from this switchboard should be fed to all other laboratories and shops that may require any of the special voltages obtainable from the machines in this laboratory.

Basic Electricity Laboratory

This laboratory will consist primarily of work tables, of benches and measuring instruments. It should accommodate students in groups of two if possible since all of the work done in this area will utilize small portable equipment items. No layout is shown for this laboratory since no special treatment is required. An example of laboratory table construction is shown that is particularly efficient where limited space is available. It can serve three purposes:

A work area for laboratory experiments;
An assembly area for lecture and discussion;
A storage area for instructional equipment.

Being of unit construction, this table can be made in sections and arranged in several ways to fit existing space.

Construction is of standard materials using conventional assembly methods. It is recommended that the working surface be covered with vinyl floor covering material and that asbestos or fiber mats be used to protect the surface during any work that might damage the surface.

Power service outlets may be installed in the 9 x 8 wiring channel on the rear of the table, and if desired, on the front edge of the bench. The continuous channel simplifies the installation of power circuits and other special service—antenna, coaxial cable, etc.

Electrical Circuit Laboratory

If an additional laboratory is to be provided for service, maintenance and repair activities, it might include some of the equipment shown in the layout shown. This area requires relatively heavy flat-topped tables. Provision should be made to supply the power for this laboratory through the main distribution panel in the power laboratory. This makes all power sources available for the work tables, including the output of the special voltage generators.

Motor Test Bench

A typical example of a fixture that might be used in this sort of laboratory is the motor test bench shown. This fixture might be used for routine testing of small motors and appliances or for certain basic instruction units involving testing and measuring procedures.

Meter and Instrument Storages

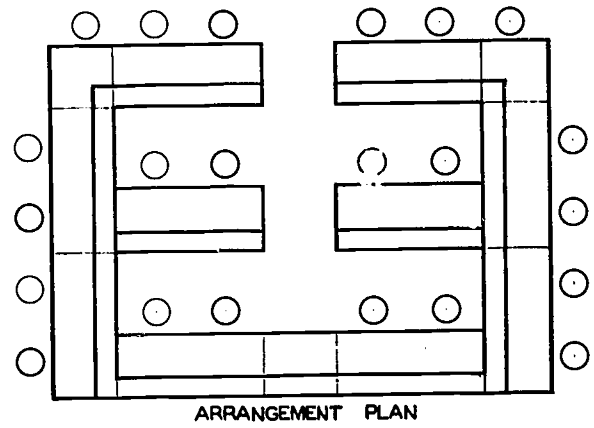
Testing and measuring instruments range from the simple to the complex, from rugged to delicate, and are correspondingly inexpensive or costly. In some cases accessibility to students is important and in other cases it is necessary to limit the use of the equipment to instructional personnel. Provisions should be made for equipment of all types.

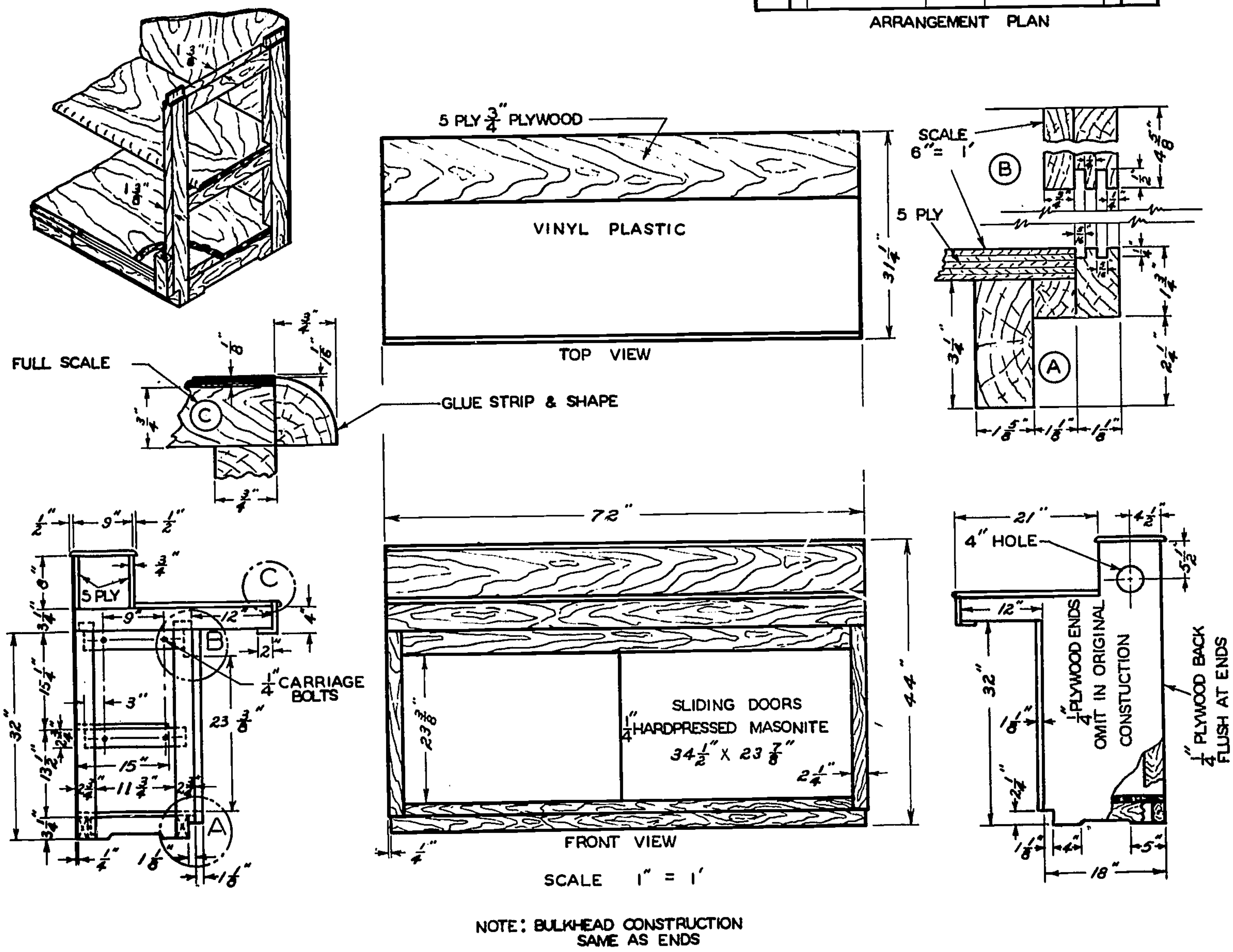
Two methods of meter storage are shown. The glass-protected cabinet, if provided with locks, has the advantage of flexibility in that it can be placed in the most convenient section of the laboratory. This method offers protection for expensive instruments while at the same time it makes them readily available and easy to locate.

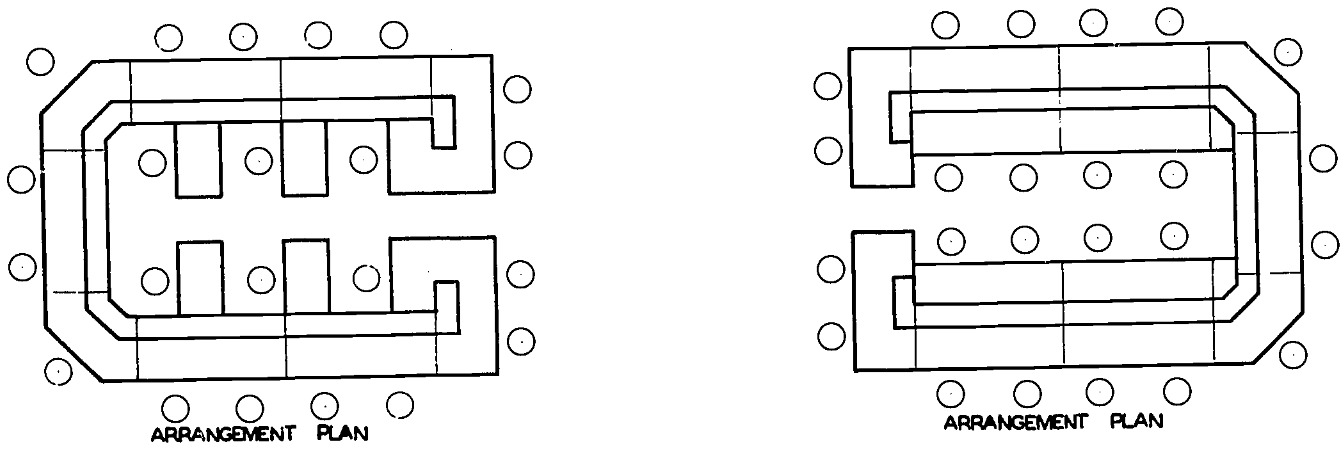
LABORATORY TABLES

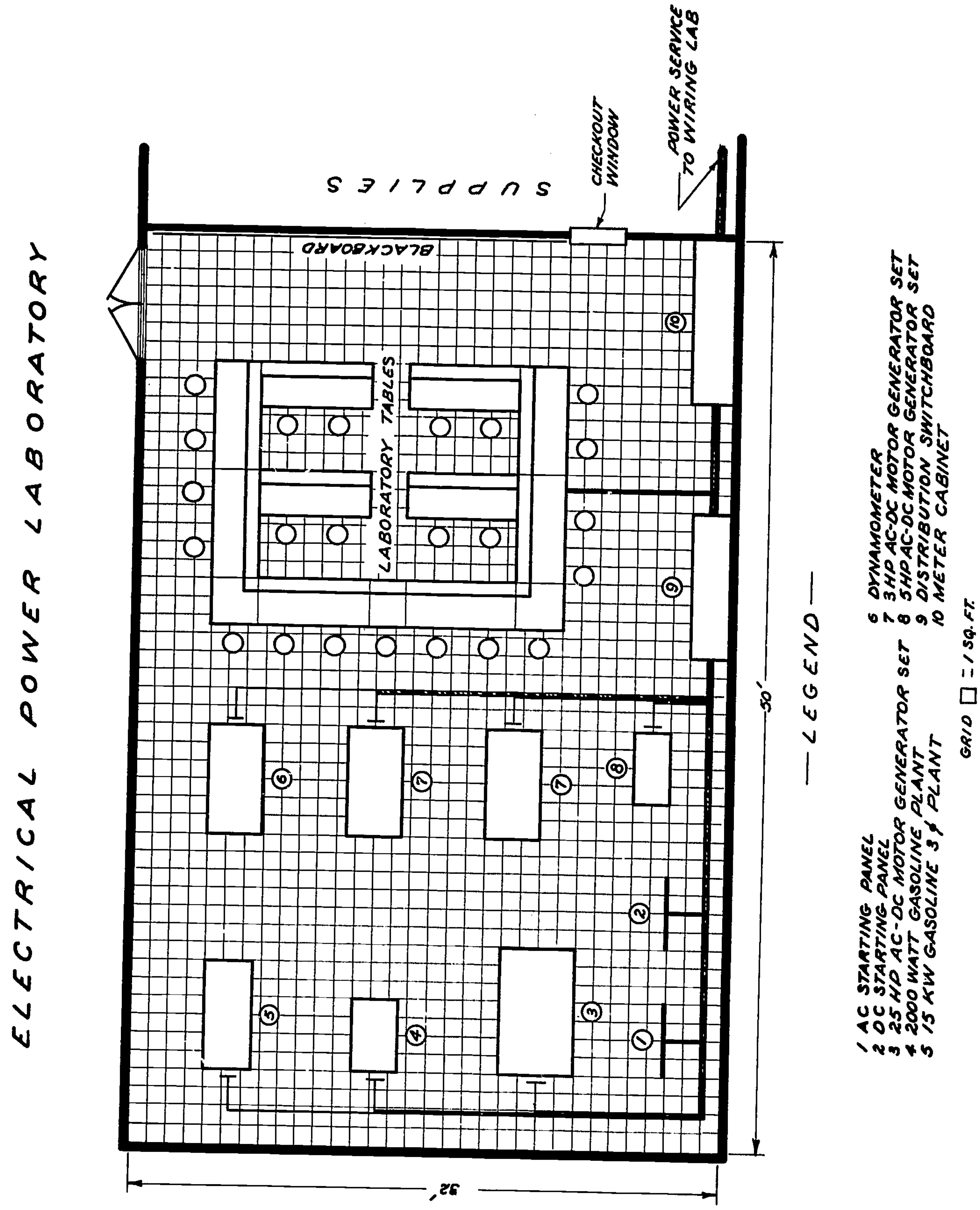
DESIGNED FOR

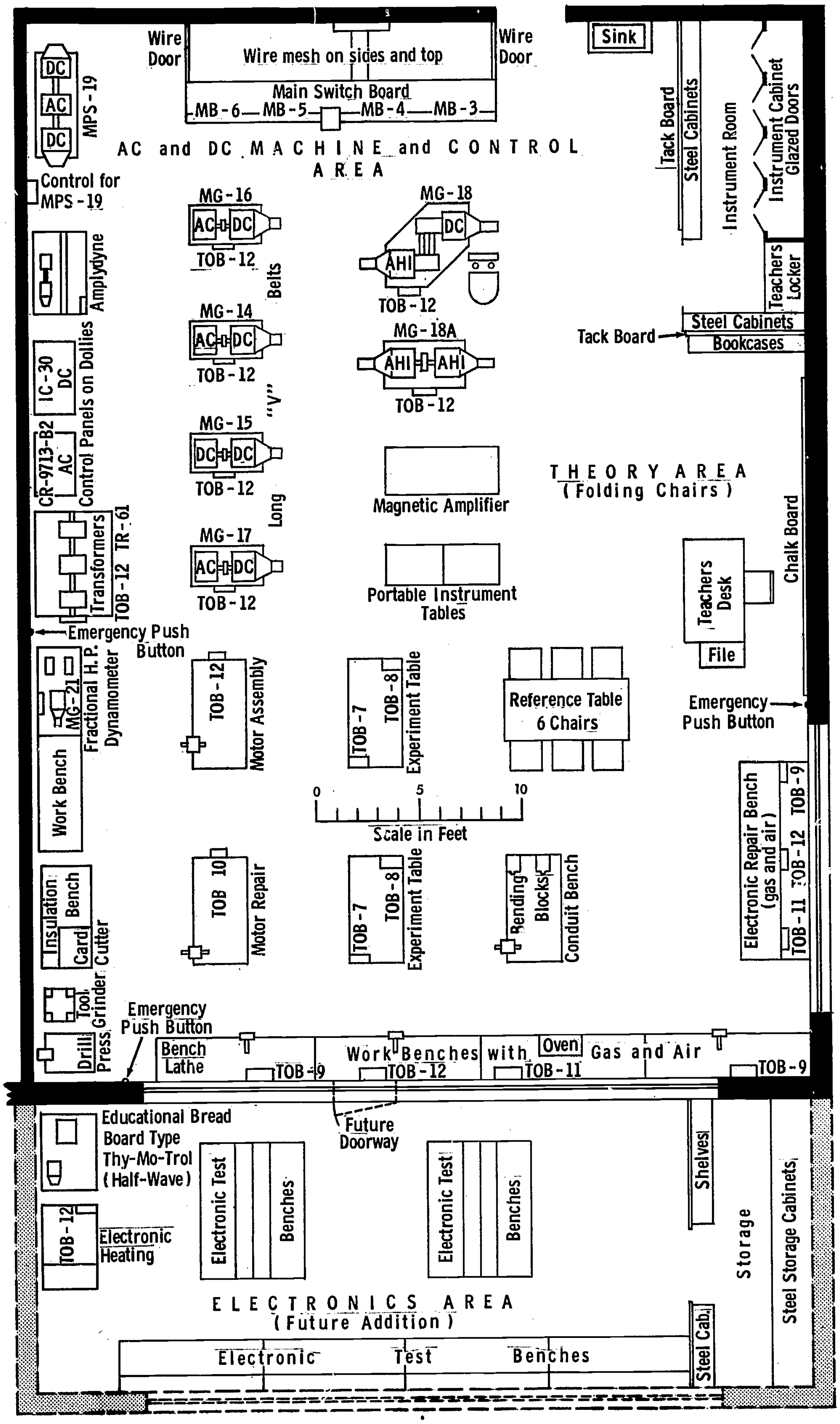
ELECTRONICS OR ELECTRICAL INSTRUCTION

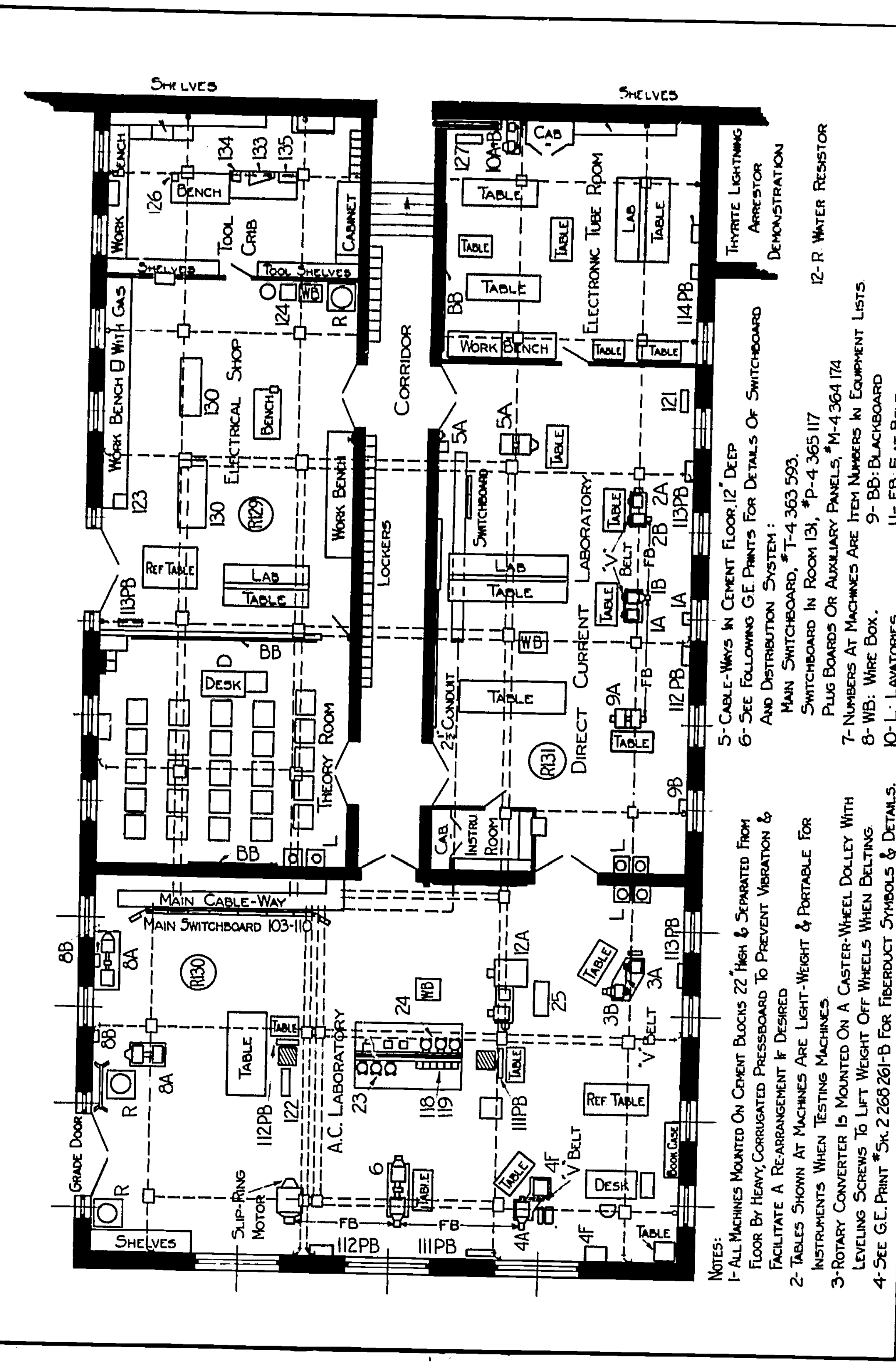




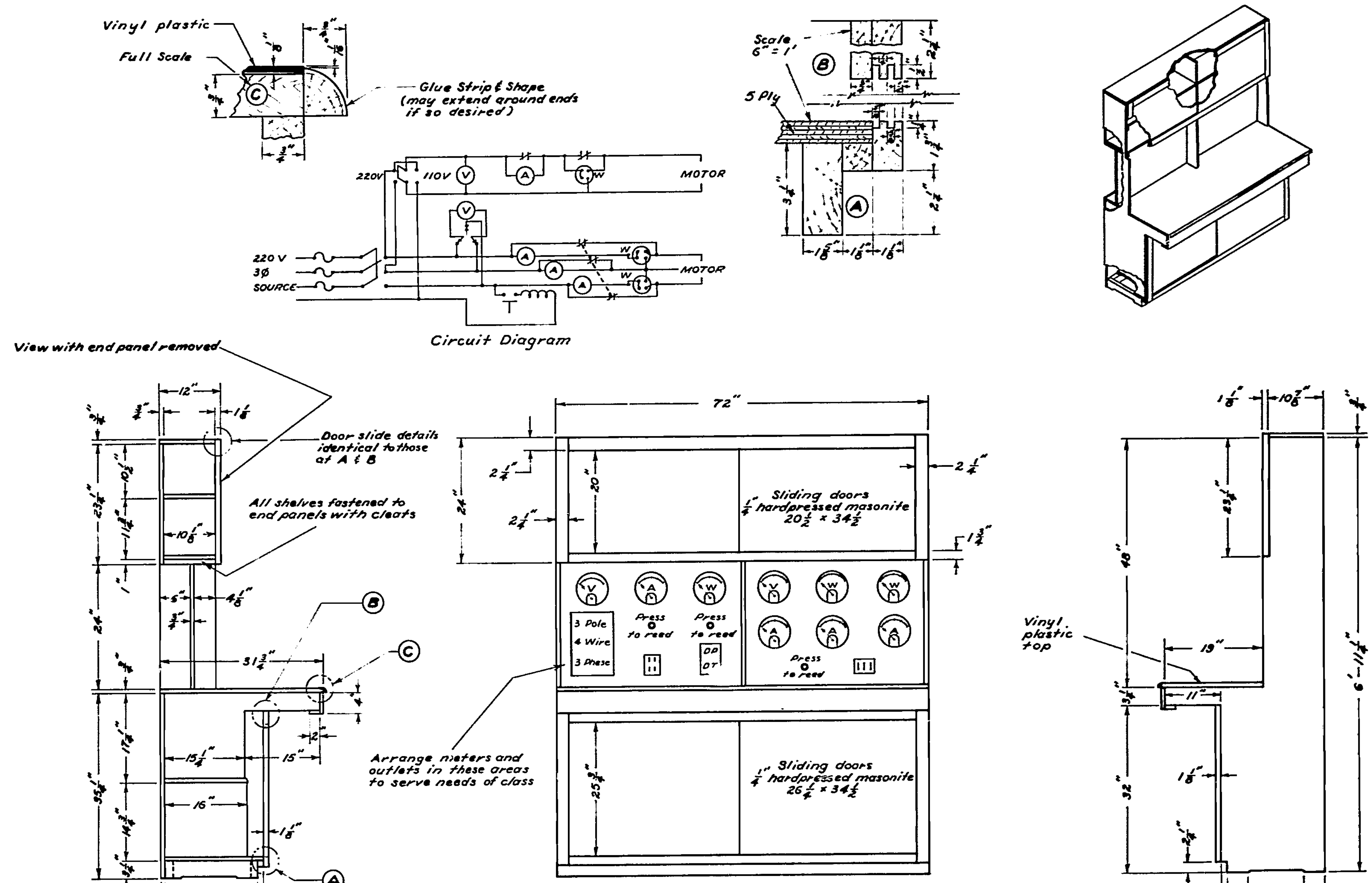



ELECTRICAL POWER LABORATORY
SUPPLIES
CHECKOUT WINDOW
POWER SERVICE TO WIRING LAB
BLACKBOARD
LABORATORY TABLES
50'
32'
— LEGEND —
1 AC STARTING PANEL
2 DC STARTING PANEL
3 25 HP AC-DC MOTOR GENERATOR SET
4 2000 WATT GASOLINE PLANT
5 15 KW GASOLINE 3 φ PLANT
6 DYNAMOMETER
7 3 HP AC-DC MOTOR GENERATOR SET
8 5 HP AC-DC MOTOR GENERATOR SET
9 DISTRIBUTION SWITCHBOARD
10 METER CABINET
GRID □ = 1 SQ. FT.


Wire Door
Wire mesh on sides and top
Wire Door
Main Switch Board
MB-6 MB-5 MB-4 MB-3
Sink
DC AC DC MPS-19
Control for MPS-19
AC and DC MACHINE and CONTROL AREA
Tack Board
Steel Cabinets
Instrument Room
Instrument Cabinet Glazed Doors
MG-16 AC DC TOB-12
MG-18 DC AHI TOB-12
Teachers Locker
Amplydyne
Belts
MG-14 AC DC TOB-12
MG-18A AHI AHI TOB-12
Tack Board
Steel Cabinets
Bookcases
IC-30 DC
CR-9713-B2 AC
Control Panels on Dollies
"V"
MG-15 DC DC TOB-12
Long
Magnetic Amplifier
THEORY AREA (Folding Chairs)
Chalk Board
Transformers TOB-12 TR-61
MG-17 AC DC TOB-12
Portable Instrument Tables
Teachers Desk
File
Emergency Push Button
MG-21 Fractional H.P. Dynamometer
TOB-12 Motor Assembly
TOB-7 TOB-8 Experiment Table
Reference Table 6 Chairs
Emergency Push Button
Work Bench
0 5 10
Scale in Feet
Insulation Bench
Card Cutter
TOB 10 Motor Repair
TOB-7 TOB-8 Experiment Table
Bending Blocks
Conduit Bench
Electronic Repair Bench (gas and air)
TOB-9 TOB-12 TOB-11
Tool Grinder
Emergency Push Button
Drill Press
Bench Lathe
Work Benches with Oven Gas and Air
TOB-9 TOB-12 TOB-11 TOB-9
Educational Bread Board Type Thy-Mo-Trol (Half-Wave)
Future Doorway
Electronic Test Benches
Electronic Test Benches
Shelves
Storage
Steel Storage Cabinets
TOB-12 Electronic Heating
ELECTRONICS AREA (Future Addition)
Electronic Test Benches
Steel Cab.

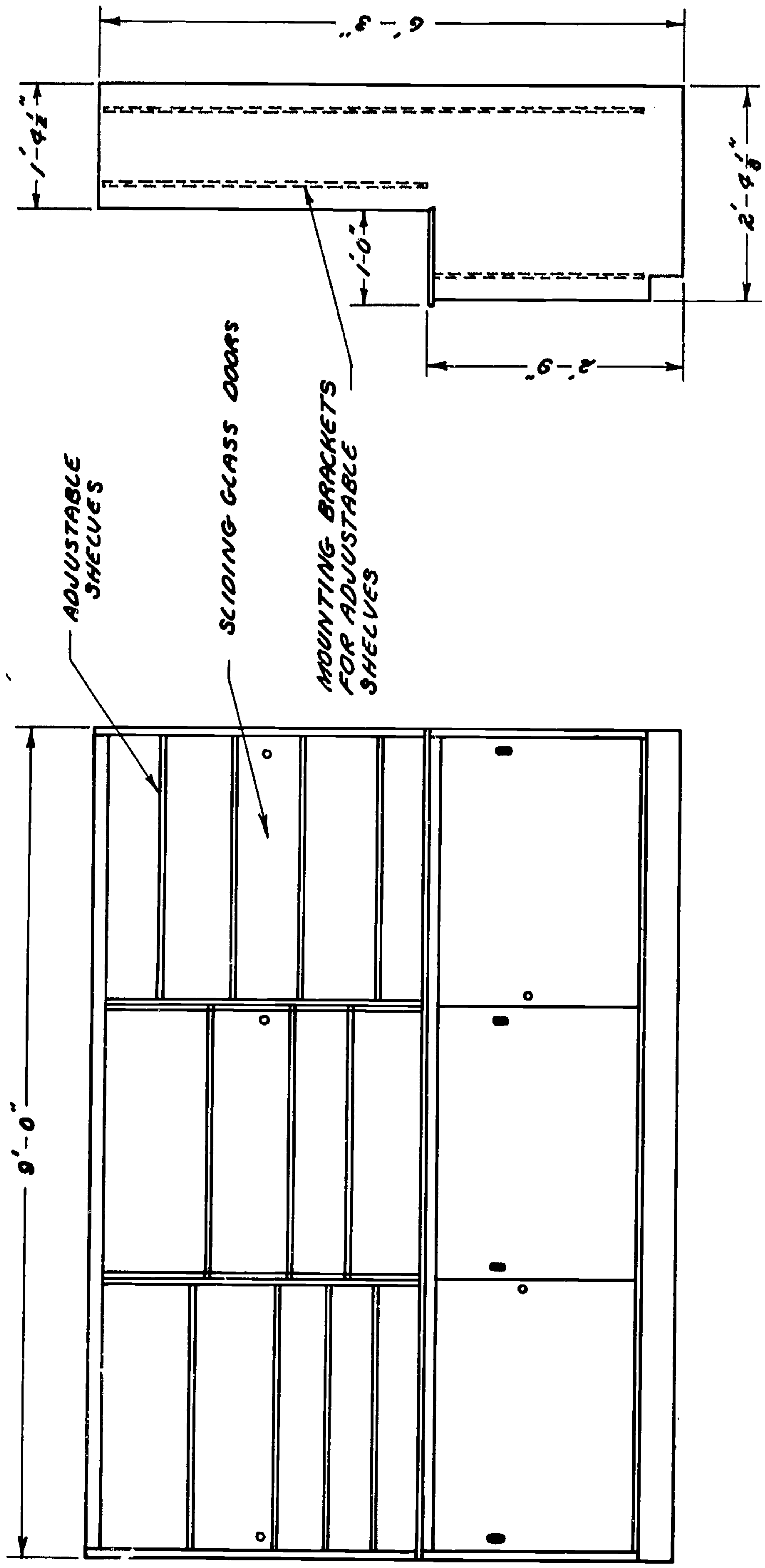


Electrical Shop & Laboratories

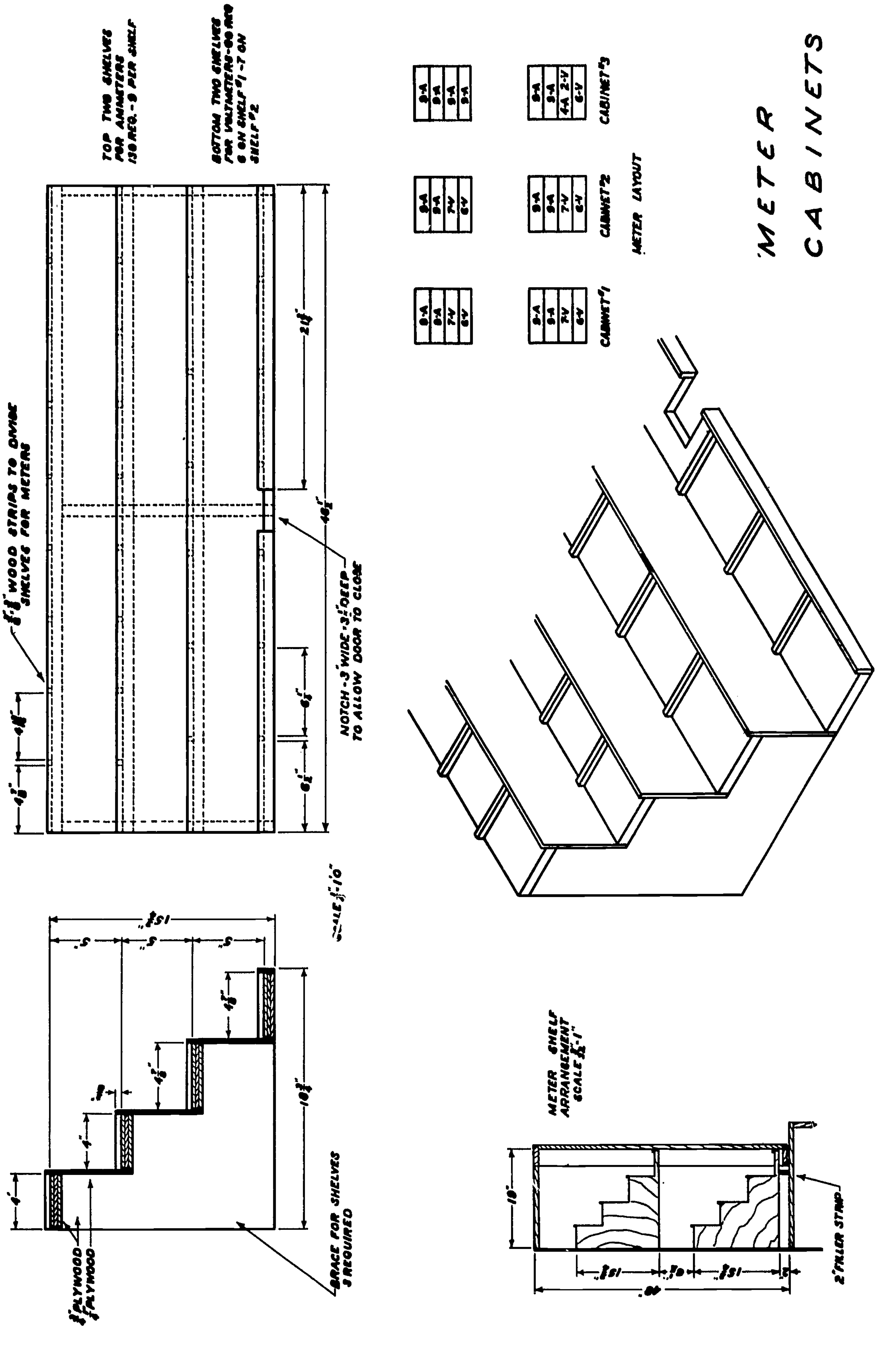


MOTOR TEST BENCH FOR ELECTRICAL LABORATORY

Scale $\frac{3}{32}$ = 1

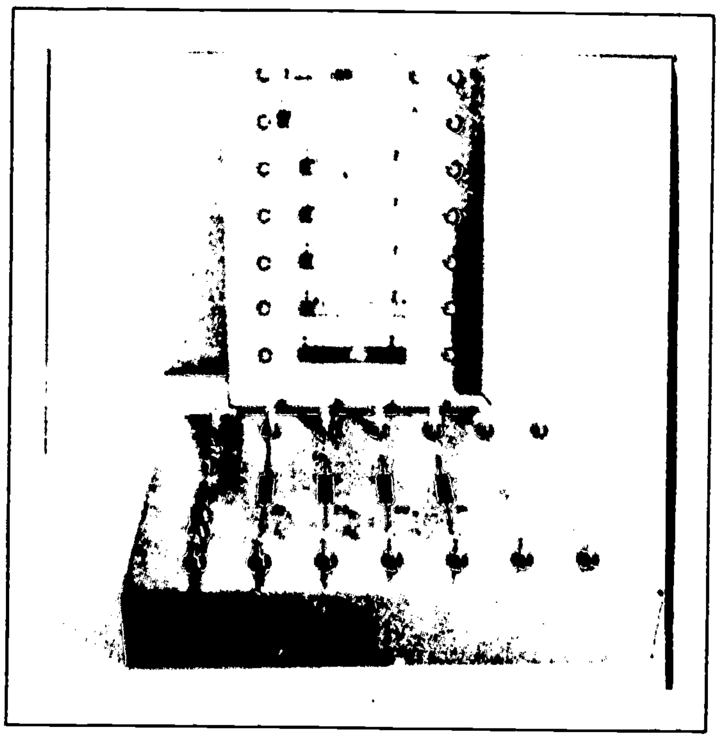


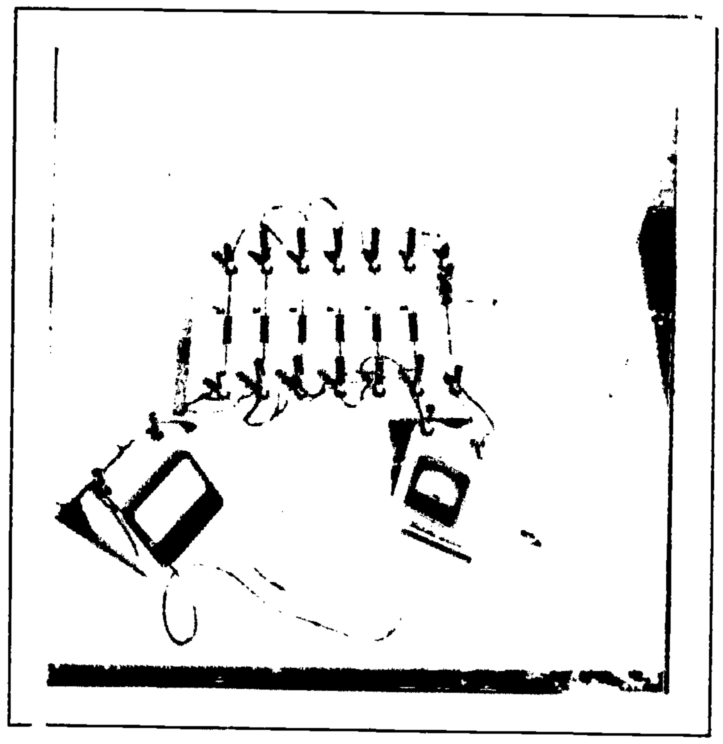
METER CABINETS


METER CABINETS
METER LAYOUT
CABINET #1
CABINET #2
CABINET #3
METER SHELF ARRANGEMENT
BRACE FOR SHELVES 3 REQUIRED
2" FILLER STRIP

Trainer and Meter Assemblies

Efficiency of instruction can be improved in large measure by multiple training devices especially in basic course work. An example of this is in the trainer and meter assembly shown. This rugged and versatile unit combines the parts and instrument necessary for the study of basic direct current circuits and is designed to be used with a low voltage power source. The units may be stacked for storage when not in use. A parts list is included.





TRAINER & METER ASSEMBLIES

Parts List for Trainer

For teaching Ohm's Law—Series, Parallel, and Series-Parallel Circuits; Kirchhoff's Law.

Quantity	*Item*
1	Chassis—12″ 17″ x 3″ aluminum
16	Terminals
14	½″—No. 6–32 machine screws
14	No. 6–32 machine screw nuts
14	No. 6 Lock washers
1	Fuse holder
1	Fuse—10 amp.
1	Toggle switch SPST—6 amps.—125 volts
6 ft.	Extension Cord, with pug cap and 2 banana plugs
4 ft.	Hook-up wire
12	Connecting jumpers with banana plugs 2—20-inch jumpers 2—16-inch jumpers 4—10-inch jumpers 2—6-inch jumpers 2—4-inch jumpers
2	Test probe leads
1	10 Ohms—80-watt resistor
2	25 Ohms—50-watt resistor
1	50 Ohms—50-watt resistor
1	75 Ohms—50-watt resistor
1	100 Ohms—50-watt resistor

Parts List for Meter Assembly

Quantity	*Item*
1	Meter (voltmeter or ammeter)
1	Meter case aluminum (to fit above meter)
2	Terminals
2	Lugs
1	Fuse holder (for ammeters only)
1	Machine screw and nut
1½ ft.	Hook-up wire
1	Fuse (for ammeters only)
	Solder

APPENDIX C—Equipment and Supplies

A minimum list of equipment is suggested as a skeleton requirement for the curriculum. It is limited to standard items that would be usable in any electrical curriculum and the list includes five sections: power laboratory equipment, demonstration equipment, equipment for students use, tools and equipment for maintenance, and supplies.

It is expected that instructional personnel assigned to this area of instruction will supplement these recommendations. Additional items of equipment and supplies will need to be added as the instructional program grows and develops. Provision should be made for this expansion. At the outset of a program, however, it is probably better to be conservative in purchasing equipment. Adding equipment as it is needed is one way of assuring that only needed equipment will be purchased.

Prices for equipment and supplies are based upon best estimates available on January 1, 1960.

Suggested Equipment for Electrical Technology

Power Laboratory Equipment

Item	Quantity	Description	Estimated cost Jan. 1, 1960
1	1	15 KW 20/208 volt 3 phase gasoline alternator electric plant	$1,500.00
2	2	Motor generator lab set, table mounted consisting of 3 hp D.C.—1 generalized A.C. machine tachometer, torque meter, brush motor as Bulletin 191, Dec. 1958	4,700.00
3	1	Distribution switchboard with indicating lights and 3 phase, 9 KVA, 60f auto transformer 220/208/115v	1,050.00
4	3	1 hp, 3θ, squirrel cage, open-type motors	165.00
5	1	1 hp, dynamometer, absorption type, Model 1100	450.00
6	2	½ hp, 120v, 60f split-phase motor type C-7A	33.44
7	2	½ hp, 120v, 60f capacitor motor	49.72
8	2	¾ hp, 125v, D.C. motors	194.00
9	1	½ hp, 120v, 60f repulsion start induction run motor	49.60
10	1	A.C. magnetic control starting panel, 3 hp	1,500.00
11	1	D.C. magnetic control starting panel, 3 hp	1,020.00
12	2	0.25 KVA auto transformer 230/115v	18.00
13	1	300 KA, 1-phase hand operated induction regulator	416.29
14	4	Loading resistor racks	1,459.20
15	1	Instrument comparator	1,400.00
16	1	Ed. set 5 hp, A.C. motor, D.C. generator set with exploring coils	1,363.30
17	2	Frequency meter	46.00
18	10	10″ rheostats, 2 each	$170.00
19	2	Size 1 general purpose magnetic switch and buttons	46.40
20	2	Size 1 magnetic starters, combination reversing and buttons	163.20
21	1	3- to 5-hp induction motors with all coils brought out to external terminals	----------
22	1	Synchroscope, 220-250v	83.00
23	1	Diactor voltage regulator	289.90
24	1	Voltage regulator	275.00
25	1	100-125v power factor meter	96.00
26	2	Current transformers 50/5 amps, through type	18.00
27	2	Current transformers, through type, 100/5 amps	36.00
28	3	70w voltage drum switches	13.50
29	1	8″ dial depramometer scales 0-5 lb	18.00
30	1	8″ dial depramometer scales 0-25 lb	18.00
31	1	A.C. to D.C. motor generator sets 15 KVA, 25 hp, 220v with rheostat	1,160.00
32	50	Steel stools with backs	330.00
33	1 lot	Shop built laboratory benches as per drawing; usual lab arrangement	750.00
34	2	Meter cabinets as per drawing	350.00
35	1	2,000-watt gasoline plant, 120v, 60f, A.C. generator, manual start	554.00

Demonstration Equipment

Item	Quantity	Description	Estimated cost Jan. 1, 1960
1	2	Kit amplifier	$219.90
2	2	Kit audio generator	99.90
3	3	Crows model 500-G demonstrator with 4-term. meter and cabinet	399.00
4	1	Lecture millimeter (7") for lecture	47.50
5	2	Universal Scientific Crow model 250 rotating electric machines	1,570.00
6	2	Kit impedance, bridges	119.00
7	1	Electronic switch kit	31.95
8	1	Projection lantern	205.00
9	2	220v, 15a 3-wire KWH meter	34.60
10	2	22v, 15a, 3-wire KWH meter	34.60
11	2	220v, 15a, 3-wire KWH meter	34.60
12	1	2½ element, 220v, 15a, KWH meter	48.00
13	1	3 element, 220v, 15a, KWH meter	74.00
14	1	115v, 15a, Thermal demand meter with KWH Type HW-2, 120v	120.40
15	2	KWH standard with snap switch	$492.00
16	2	Phantom load boxes	600.00
17	3	Electrophorous	14.85
18	3	Electroscopes	12.75
19	2	Electroscopes	35.00
20	1	Condenser attachment	
21	1	Wimhurst Static Machine	115.00
22	2	Leyden jars	5.00
23	1	Dischargers	9.50
24	1	Phase sequence meter 125/250/480v	39.60
25	1	Oscilloscope kit	79.95
26	1	Choke and resonance coils	57.50
27	1	Gravity cell, Crowfoot type	5.00
28	1	Edison storage ce"	19.95
29	1	Magnetometer	82.50
30	1	Permeameter	135.00

Suggested Supplies for Electronics Technology

Item	Quantity	Description	Estimated cost, Jan. 1, 1960
1	1	Roll manganium wire #18	$1.55
2	1 set	Straight shank high speed number set drills with stand	24.00
3	1	Electrolyte for Edison cell	5.00
4	24	#6 dry cells	20.16
5	24	#D dry cells	3.12
6	24	#AA dry cells	3.12
7	100	1-250v, 1 amp little fuses	10.00
8	200	3-250v, 3 amp little fuses	20.00
9	100	5-250v, 5 amp little fuses	10.00
10	50	10-250v, 10 amp little fuses	5.00
11	50	25-250v, 25 amp little fuses	5.00
12	2	Star drills, ¼"-12" length	
13	2	Star drills, ¾"-12" length	
14	6	8" mill files	$4.80
15	6	Half round, 10" files	11.40
16	3	8" Round files	2.70
17	3	Wire scratch brushes	1.80
18	3	Commutator slotting files 8"	4.20
19	1	¾" Carbide tipped cement drill	1.33
20	1	½" Carbide tipped cement drill	1.78
21	1	⅝" Carbide tipped cement drill	2.18
22	6	1-pt. oil cans	4.50

Suggested Laboratory Equipment for Student Use in Electrical Technology

Item	Quantity	Description	Estimated cost Jan. 1, 1960
1	10	1" micrometers	$135.00
2	10	Wire gauges	55.50
3	12	Ohm law trainers	450.00
4	12	0-1 DC ammeters; base, fuse, and terminals	155.16
5	12	0-5 DC ammeters; base, fuse, and terminals	155.16
6	6	0-25 DC ammeters; base, fuse, and terminals	77.58
7	12	0-30 DC voltmeters	144.72
8	10	0-150 DC voltmeters; base, fuse, and terminals	120.60
9	15	0-1 AC ammeter; base, fuse, and terminals	172.35
10	15	0-5 AC ammeter; base, fuse, and terminals	172.35
11	10	0-10 AC ammeter; base, fuse, and terminals	117.90
12	5	0-25 AC ammeter; base, fuse, and terminals	58.95
13	10	0-50 AC voltmeter; base, fuse, and terminals	120.10
14	15	0-300 AC voltmeter; base, fuse, and terminals	88.85
15	6	0-500 AC voltmeter; base, fuse, and terminals	102.66
16	15	0-300 Wattmeters, 150v, 4a; base, fuse, and terminals	419.70
17	6	0-300 Wattmeters, 300v, 10a; base, fuse, and terminals	179.88
18	3	0-300 Wattmeters, 300v, 20a; base, fuse, and terminals	99.84
19	12	Students' demonstration cells	42.00
20	10	Students' demonstration cells	135.00
21	3	Resistance decade (heath kit) boxes to 9.999 ohms	58.50
22	2	Wheatstone bridge #12171 with galvanometer #12421	135.00
23	1	Megger insulation tester 0-1,000 megohms, 500-volts test	$275.00
24	16	3 terminal coils	2,022.40
25	8	Laminated iron "U" coils	1,104.00
26	8	Flat coils	775.68
27	8	Laminated cores	563.20
28	2	Clamp-on ammeters with gauge	
29	12	Alnico bar magnets	18.00
30	12	Alnico horseshoe magnets	18.00
31	15	Magnetic compass	2.85
32	5	Carter iron filings	4.25
33	12	Friction glass rods	4.20
34	12	Hard rubber rods	8.40
35	12	Exciting pads, wood felt	7.20
36	12	Exciting pads, silk	6.00
37	12	Electroscope	33.00
38	5	Telegraph instruments	92.50
39	6	Wheatstone bridges slide-wire form #83191	67.00
40	6	Galvanometers	163.50
41	6	Tachometers	421.50
42	12	Oil filled 15 mfd, 600 volt capacitors	156.24
43	12	0.25KVA transformer 460 to 220/110 volts	1,500.00
44	6	Half-wave instrument rectifier	6.30
45	12	Instrument cases	15.48
46	3	Resistance-cap bridge, kit	59.85

Tools and Machines for Constructing and Maintaining Electrical Equipment

Item	Quantity	Description	Estimated cost, Jan. 1, 1960
1	1	Engine lathe, 3′ bed, 9″ swing complete with 3-phase motor 220v, quick-change gear, 4 & 3 jaw chucks, universal scroll chuck, plus needed tools	$369.00
2	1	Pedestal grinder, 1 hp, 220v motor with brush and stone	269.00
3	1	No. 3 press arbor with stand	165.00
4	3	Sets ½″ drive socket wrenches, ⅜″ thru ¾″	15.80
5	2	Sets box-end wrenches	38.55
6	12	Ball peen hammers (3¾ lb.; 6 1-lb., and 3 2-lb.)	33.00
7	4	8 oz. Plastic hammers	14.00
8	2	8″ C clamps	3.04
9	2	6″ C clamps	2.08
10	1	Set 1/16″ through ½″ high-speed twist drills with stand	40.90
11	1	Stud driver (22 caliber)	134.50
12	1	½″ Electric drill, 115v, 500 rpm	50.20
13	2	¼″ Electric drill, 115v, 500 rpm	63.60
14	1	Slot insulation folder	89.50
15	6	Coil tampers 3/16″ x ⅞″ face	16.50
16	4	Coil tampers, 5/16″ x 1¼″ face	12.00
17	4	Wedge drivers, ⅛″ x ⅝″	24.00
18	3	Armature air gap gages	9.25
19	1	Bearing tool	26.50
20	1	Blind bushing attachment	4.50
21	1	Snap-on gear puller	12.85
22	1	Snap-on gear puller	8.00
23	1	Shaft straitner attachment	
24	1	Spiral expansion self-alignment reamer with taper collets, ⅜″, 7/16″, ½″, 17/32″, 9/16″, ⅝″, 21/32″, 11/16″, ¾″, 13/16″, 1″	79.00
25	3	Stator winding guns	126.00
26	1	Bench growler (110v)	57.50
27	1	Internal growler (110v)	41.50
28	6	Sets coil cheeks	60.00
29	1	Paint spray outfit, 1-qt. gun	78.95
30	1	Coil winder drive	649.50
31	1	Universal winder head	85.00
32	1	Balancing ways	99.50
33	1	Battery charger, 5 amps, 0–28v	42.95
34	1	Tap and die sets 4–12 machine screw case (T)	13.30
35	1	Tap and die sets ¼″ through ½″ with case (T)	42.40
36	1	Heavy-duty pipe reamer, ⅛″–1¼″	10.40
37	1	Heavy-duty pipe reamer, ⅛″–2″	15.40
38	1	Bench chain vise, 2″	9.10
39	1	Rachet handle complete with ½, ¾, 1, ¼″ conduit pipe dies	32.65
40	4	10″ Pipe wrenches	16.60
41	2	14″ Pipe wrenches	11.10
42	4	7½″ Diagonal side cutting pliers	18.60
43	4	9″ Electrician pliers	25.00
44	6	Duck-bill pliers, 7¾″	20.10
45	6	4″ Square blade, plastic handle screwdriver #SD44	7.20
46	6	6″ Square blade, plastic handle screwdriver #SD48	9.00
47	6	8″ Square blade, plastic handle screwdriver #SD46	12.60
48	2	12″ Square blade, plastic handle screwdriver #SD412	$6.20
49	2	5″ Offset screwdriver, #030	2.10
50	6	6′ folding rule	7.20
51	6	Pliers	12.78
52	1	1″ Wood chisel	1.93
53	1	¾″ Wood chisel	1.80
54	1	½″ Wood chisel	1.60
55	4	Adze eye hammers, 13 oz. head	9.32
56	4	Ripping hammers, 1¼″	10.00
57	1	10″ Tin snips	3.25
58	2	½″ Cold chisels	3.70
59	2	Center punches	2.60
60	1	1″ Cold chisel	4.85
61	2	24″ Pinch bars	11.40
62	6	Hacksaw frames	8.70
63	10	Hacksaw blades (32T)	2.00
64	10	Hacksaw blades (24T)	2.00
65	3	Hand saws	15.03
66	3	Keyhole saw	3.51
67	12	Wooden file handles	2.70
68	12	100 w, 115 v, soldering irons	74.40
69	3	220 w, 115 v, soldering irons	23.40
70	1	500w, 115v soldering iron	10.40
71	2	1-quart blowtorch	47.00
72	2	Extension lamps with reflectors	3.00
73	1 set	Knockout punches for ½″, ¾″, 1″, 1¼″ conduit	9.90
74	1	120v, 800w, Drying oven (precision)	197.50
75	2	Ideal fish tape ⅛″ x 0.060 x 50′	2.12
76	1	Ideal fish tape ¼″ x 0.060 x 100′	2.11
77	1 set	3 Hickeys, ½″–¾″–1″	11.20
78	2	EMT benders, ½″	5.72
79	1	EMT benders, ¾″	4.85
80	1	EMT benders, 1″	7.24
81	2	Fuse puller	2.00
82	2	Fuse puller	5.90
83	3	Fish tape pullers	5.25
84	1	½″ drill press, pedestal model with motor and pulley	221.95
85	4	Adjustable wrenches, 6″ D76	13.00
86	4	Adjustable wrenches, 8″ D76	17.60
87	2	Adjustable wrenches, 10″, D10	12.00
88	2	Adjustable wrenches, 15″, D15	18.00
89	1	Rachet rigid conduit bender ½″, ¾″, 1″	1.30
90	3	Machinist vises, 3½″ jaws	100.50
91	1	Machinist vises, 5″ jaws	68.70
92	2	Magnesium step ladders, 6′	44.88
93	1	Magnesium step ladders, 10′	39.94
94	4	V rachet braces	[illegible]
95	4	Auger bits, sets (6 bits/set)	7.50
96	1	Corner bit brace	15.13
97	1	Bit extension	2.04
98	2	4 lb./pair soldering coppers	3.80
99	1	2 lb./pair soldering coppers	2.00
100	2	Phillips head screwdriver	1.50
101	2	Phillips head screwdriver	2.04
102	2	Phillips head screwdriver	4.06